SCIENCE EXPERIENCES
WITH
INEXPENSIVE EQUIPMENT

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INEXPENSIVE EQUIPMENT

by

CARLETON JOHN LYNDE, PH.D.
PROFESSOR EMERITUS OF
PHYSICS AND HOUSEHOLD ENGINEERING
TEACHERS COLLEGE, COLUMBIA UNIVERSITY

SECOND EDITION

D. VAN NOSTRAND COMPANY, INC.
PRINCETON, NEW JERSEY
TORONTO LONDON
NEW YORK

D. VAN NOSTRAND COMPANY, INC.

120 Alexander St., Princeton, New Jersey
257 Fourth Avenue, New York 10, New York
25 Hollinger Rd., Toronto 16, Canada

FIRST PUBLISHED AUGUST 1923

Foreword

This revised book, *Science Experiences with Inexpensive Equipment*, is the second in a series of three books on Science Experiences with simple equipment. Each book illustrates, describes, and explains 200 science experiences.

There are many excellent books which describe experiments you can make with the equipment to be found in a high school or college laboratory. These three books on Science Experiences differ from other books in this respect: they describe 600 experiences you can have *in your own home*, with equipment you have at home or can buy from local stores, and from the firms listed at the back of the book.

There is a great difference between *information* and *knowledge*. *Information* is that which *we learn from others* by seeing or reading, or by word of mouth. *Knowledge* is that which *we learn from our own experiences*. These three books enable you to acquire knowledge. You do something with equipment, *with your own hands*, and you *see*, *hear*, or *feel* something happen. You do it again and again *with your own hands* and you *see*, *hear*, or *feel* it happen again and again. Then you *know*. You have acquired *knowledge* which has become a part of your very being.

"Knowledge begins in wonder."

"All thought is based on experience."

"One experience is worth ten demonstrations."

Acknowledgments

The writer wishes to thank his colleagues, Professors Maurice A. Bigelow, Samuel Ralph Powers, Gerald S. Craig, and Frank W. Cyr, for steady encouragement in the preparation of this series of books; and Professor Parke B. Fraim, Polytechnic Institute of Brooklyn, for excellent experiences.

He wishes to thank also the following members of his classes for suggestions included in the series: Lincoln Baar, Clarence E. Baer, Frederick W. Bates, Mark P. Bedford, Joseph M. Cadbury, Eleanor Cleveland, Thomas F. Dolan, Neil C. Doren, James K. Harris, Etta Ward Hastings, Edgar M. Hoopes, John Dale Kelly, James F. Mason, Jesse V. Miller, Paul C. Mitchell, Ralph Preston, Charles E. Reck, Allan Scholtzhauer, C. Neale Stacy, Rudolph Steinberg, Karl Theman, Loring E. Tyson, Robert S. Wheelock, Lester R. Willard, and Edith Yelenfy.

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SCIENCE EXPERIENCES
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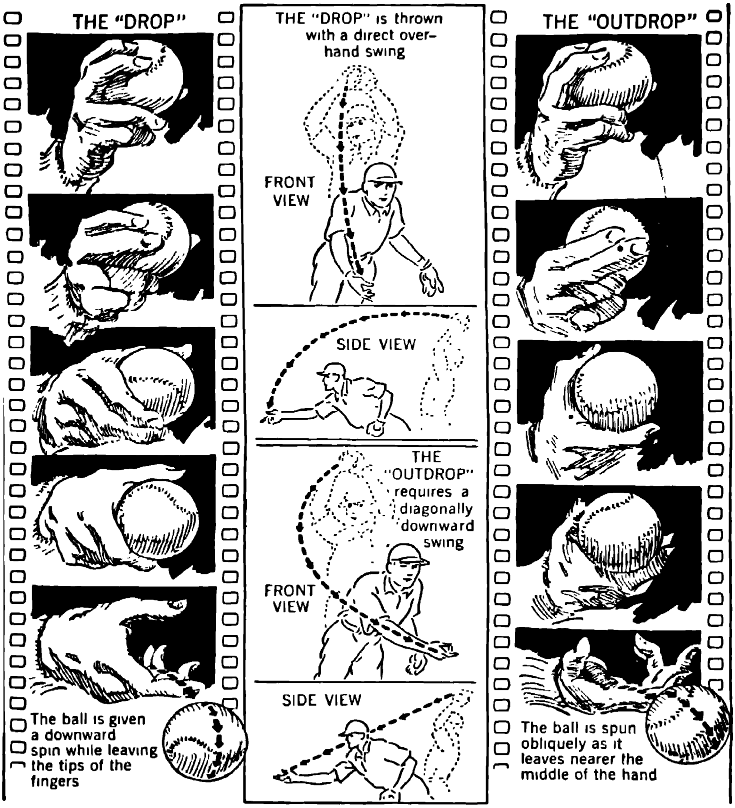
Baseball Curves and the Like

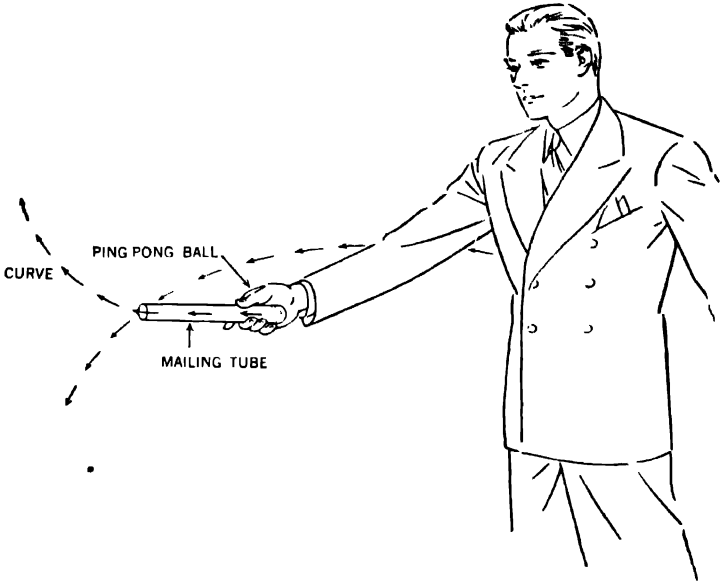

THE "DROP"
THE "DROP" is thrown with a direct over-hand swing
FRONT VIEW
SIDE VIEW
THE "OUTDROP" requires a diagonally downward swing
FRONT VIEW
SIDE VIEW
THE "OUTDROP"
The ball is given a downward spin while leaving the tips of the fingers
The ball is spun obliquely as it leaves nearer the middle of the hand

From "How to Pitch" Courtesy of A. G. Spalding and Bros., New York.

1. How to Curve a Baseball

The ball "follows its front." That is, it curves in the direction in which its front is turning.

Why? See page 229.



2. To Throw Curves with a Ping-pong Ball

Find or make a cylindrical cardboard mailing tube about 1 foot long and with an inside diameter about ½ inch larger than the outside diameter of the ping-pong ball.

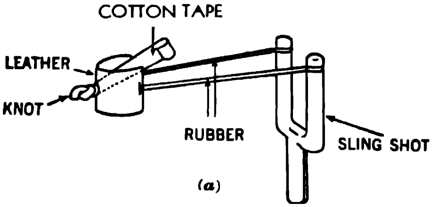
Go outside where you will have plenty of room, place the ball in the tube, and swing the tube to throw the ball.

You will throw beautiful curves but you will not have much control.

The ball will always curve in a direction opposite to that in which you swing the tube. If you swing the tube from right to left, the ball will curve from left to right, and vice versa.

The ball "follows its front." That is, it curves in the direction in which its front is turning.

Why? See page 229



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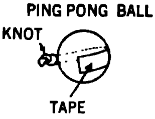

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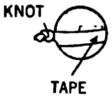

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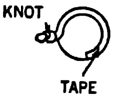

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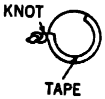


(e)

3. Another Way to Throw Curves

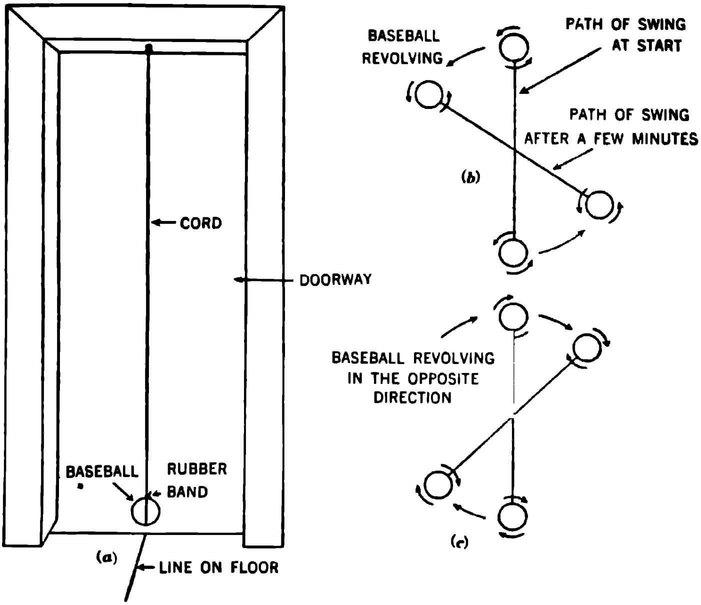
a. Use a sling-shot with arms about 4 inches high and 5 inches apart. Make a small hole in the leather, insert an 8-inch length of cotton tape and tie a knot.

b. Wet the tape and wrap it around the ping-pong ball as shown here and shoot the ball as you would a stone. It will curve *out* to the left.

c. Repeat with the tape as shown. The ball will curve *in* to the right.

d. Repeat with the tape as shown. The ball will curve *up*.

e. Repeat with the tape as shown. The ball will curve *down*.



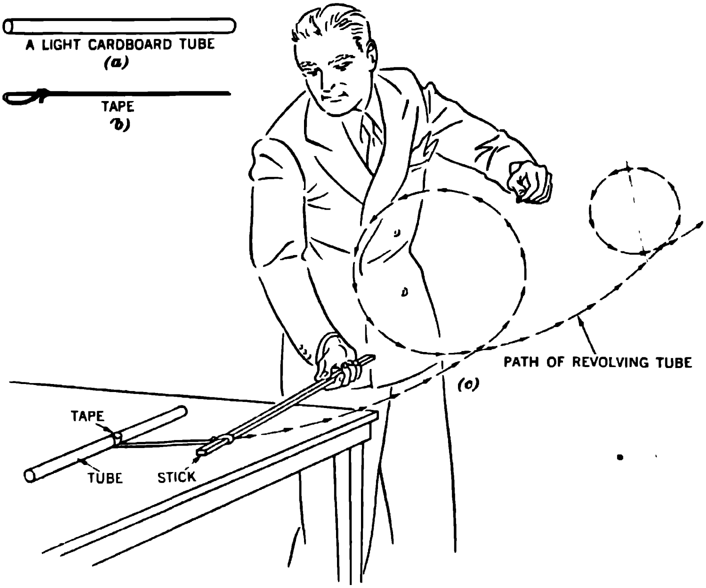
4. To Show the Sidewise Shift of a Revolving Baseball

a. Hang a baseball about 2 inches above the floor in a doorway and twirl it until the cord has been shortened about 4 inches by the twisting. Swing the baseball as a pendulum above a line drawn on the floor and it will revolve rapidly as the cord untwists.

b. If the baseball revolves as shown here, it will *follow its front* on each forward swing and move slightly to the *left*. It will also *follow its front* on each backward swing and move slightly to the *right*.

As a result, its path of swing will shift as shown.

c. If the ball revolves in the *opposite direction*, its path of swing will shift in the *opposite* direction.



5. To Make a Tube Curve Through 360° or More

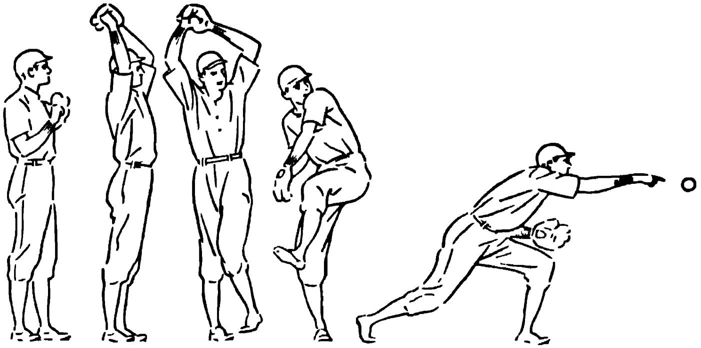
a. Find a *very light* cardboard tube about 1 inch in diameter and 1 foot to 2 feet long. The *light* cardboard tubes which come around long candles sold in the ten-cent stores are excellent. The cardboard tube from a roll of paper towels or toilet tissue may be used.

b. Buy a yard of cotton tape ½ inch to ¾ inch wide and make a 3-inch loop at one end.

c. Wind the tape around the tube *at the exact middle* in such direction that when it unwinds it will make the tube revolve with its front moving *upward.*

Place the tube on a table, insert a 3-foot stick in the loop and flick the tape rapidly.

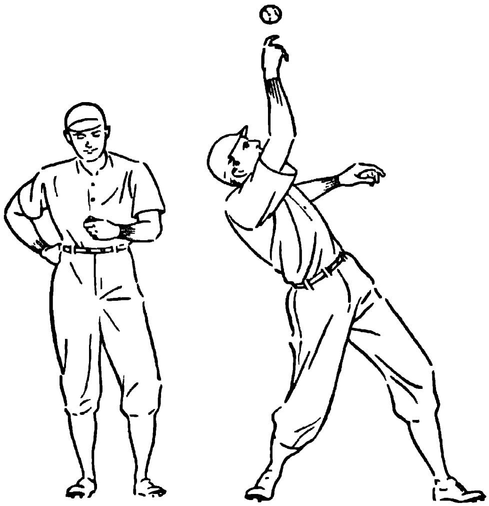
The tube will curve in the air in one complete loop and sometimes in two, as shown.



From "How to Pitch." Courtesy of A. G. Spalding and Bros., New York

6. To Pitch a Fast Ball

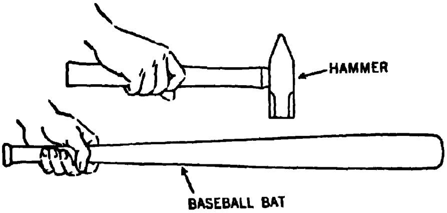
Swing your hand, arm, and body rapidly in the largest possible circle to give the ball at the circumference the greatest possible speed.



7. How Fast Can You Throw a Baseball?

Throw the ball vertically upward, while a friend takes the time in seconds from the instant the ball leaves your hand until it strikes the ground.

Half this time multiplied by 32 is the velocity in feet per second you gave the ball.



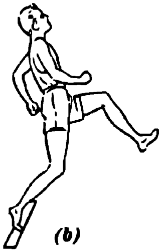
8. To Find the "Best Spot" on a Bat

Hold the bat in one hand and strike it with a hammer at each inch along its length.

You will find one spot where the bat *does not* sting your hand. This is the best spot at which to hit the ball with the bat. Mark it with a circle around the bat.

Why? See page 230.

(a)



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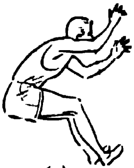


(c)

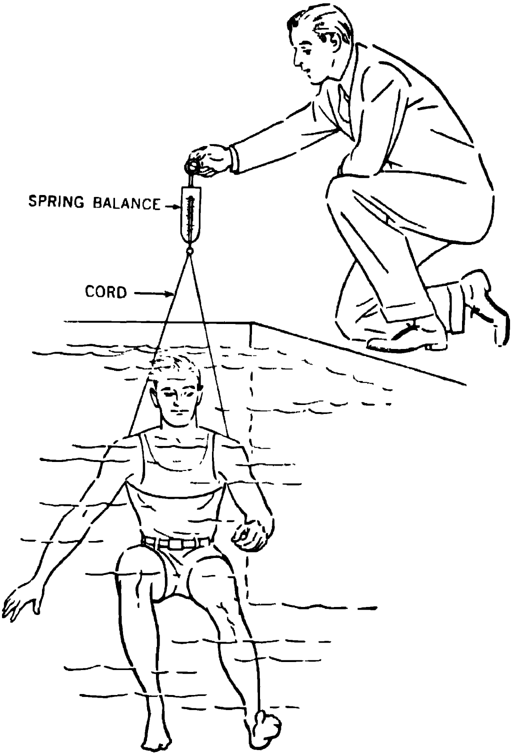
9. The Broad Jump

The next time you practice the broad jump try this:

a. Run fast.

b. Jump *upward* from the take-off.

c. The run gives you horizontal speed, the upward jump gives you time in the air. The combination gives you a long jump.



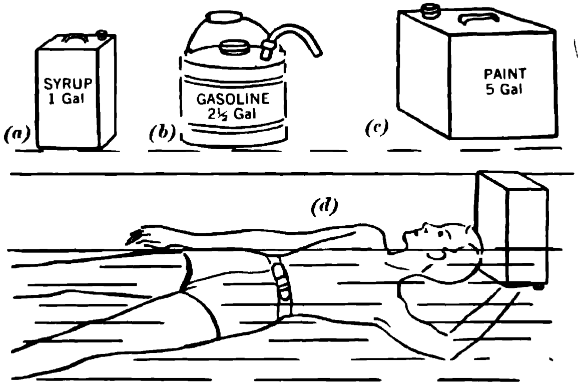
10. You Weigh Very Little in Water

At the swimming pool, tie an 8-foot cord into a 4-foot loop, pass it across your chest and under your arms and have a friend weigh you *when you have exhaled and are entirely submerged.* You will weigh very little.

Weigh a number of friends in this way.

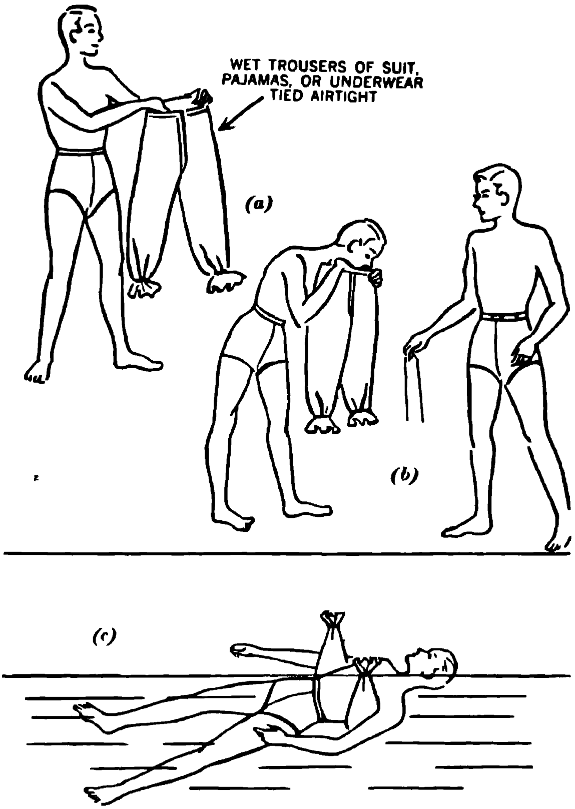
You will find that some have no weight at all—the floaters. Others will weigh from one to five pounds.

Why? See page 230.



11. Tin-Can Life Preservers

In your swimming pool, test the buoyancy of empty airtight cans such as the gallon syrup can *a*, the 2½-gallon gasoline can *b*, and the 5-gallon paint can *c*. You will be surprised at how easily they support you.

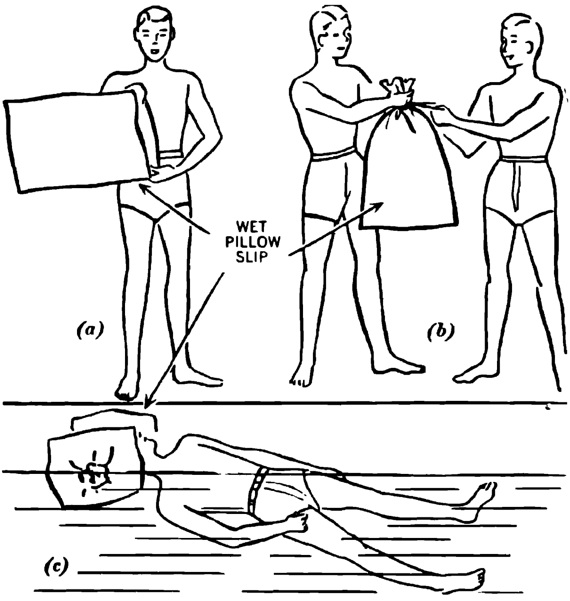

WET TROUSERS OF SUIT, PAJAMAS, OR UNDERWEAR TIED AIRTIGHT
(a)
(b)
(c)

12. Trouser-Leg Water Wings

a. Use the trousers of a suit, or pajamas, or long underwear and be sure there are no holes in them. Tie the lower end of each leg air-tight and *wet the trousers thoroughly in water.*

b. Gather the top of each leg in turn air-tight about your mouth, with your nose outside. Breathe in through your nose and puff air into the leg until it is full. Then tie the top of the leg air-tight.

c. Test the water wings.



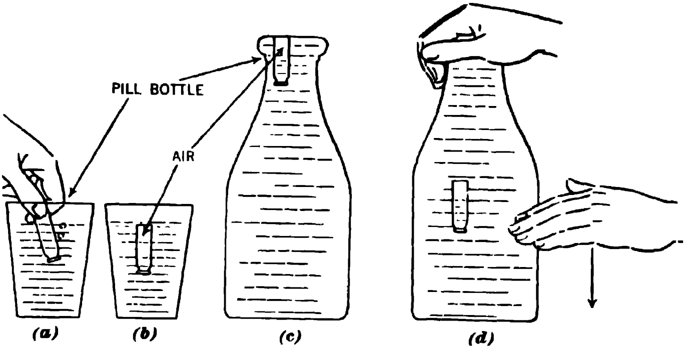
13. Pillow-Slip Water Wings

a. Select a close-woven pillow slip without holes. *Wet it thoroughly in water.* Hold the mouth of the slip open and turn it around rapidly until the slip is full of air.

b. Gather together the mouth of the slip and tie it.

c. Test the water wings.

Note. **The air is held in by the water surface films in the cloth meshes. So keep the cloth wet. You will be surprised at the strength of these films. Of course, if you squeeze the pillow slip hard enough you will break the water films and force air out.**



14. An Obedient Diver

a. Find a very small glass pill bottle. Place it mouth down in a tumbler of water and tilt it to let air escape. Let the bottle float.

b. Continue to let air escape until you see the closed end of the *floating* bottle just *under* the surface, when you look at the under side of the surface of the water through the side of the tumbler.

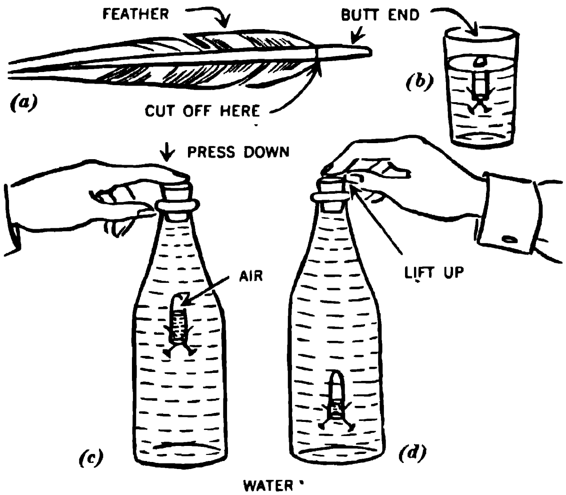
c. Put a finger over the mouth of the bottle, transfer the bottle to a quart milk bottle *full to the top* with water, and remove your finger *under water.*

d. Place the palm of your *right* hand over the mouth of the full bottle. Make a downward motion with your *left* hand and press down with your right.

The small bottle will dive.

Make an upward motion with your left hand and decrease the pressure with your right.

The bottle will come up again.



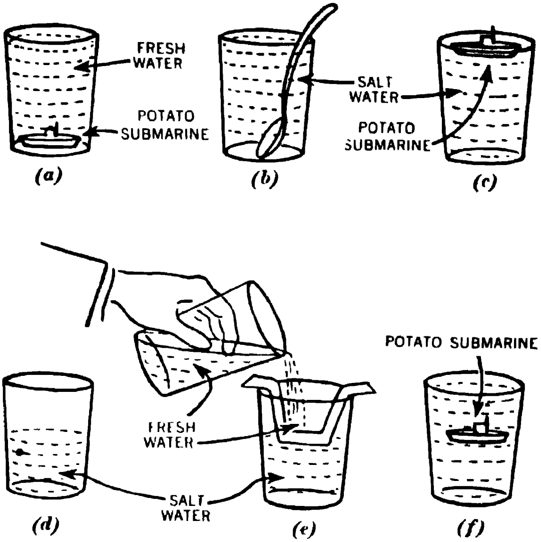
15. Another Diver

a. Use the longest feather you can find. Cut off the butt end and clean out the inside of the butt.

b. Insert tacks or thin nails near the open end until the butt floats with its closed end about one-half inch above water.

c. Place the diver in a quart pop bottle *filled to overflowing with water.* Say "Down Diver" and the magic diver will sink to the bottom of the bottle *if at the same time you secretly insert the cork and press it down.*

d. Say "Up Diver" and the magic diver will rise to the top of the bottle *if at the same time you secretly lift the cork.*



16. A Potato Submarine

a. Cut out of a raw potato a submarine about 1½ inches long, and use a half-match for a periscope. Place the submarine in a tumbler of fresh water, and it will sink to the bottom.

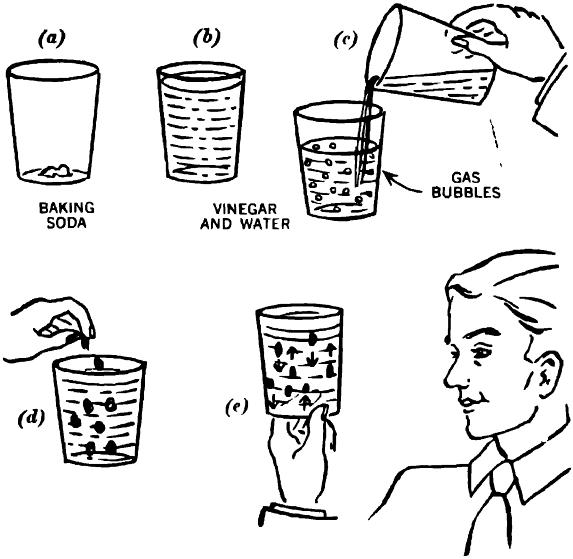
b. Stir two heaping tablespoonfuls of salt in the water.

c. The submarine will float on the surface.

d. Empty out half of the salt water.

e. Fold a piece of newspaper, 8″ x 2½″, down on the salt water to prevent mixing, and fill the tumbler with fresh water. Remove the paper slowly.

f. Put the submarine in the water and it will submerge to half the depth of the tumbler.



17. Apple-seed Pearl Divers

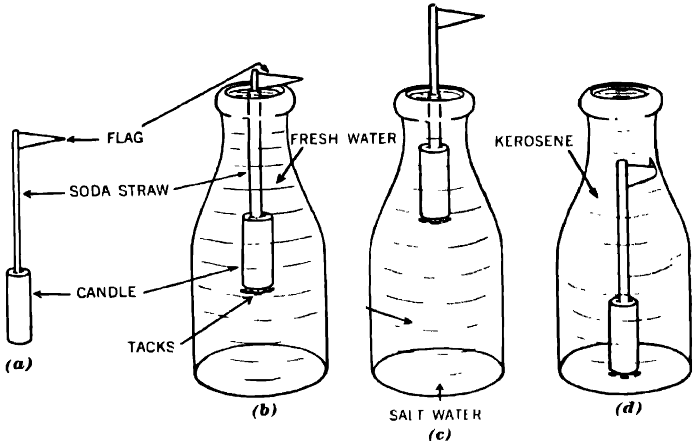
a. Put a level teaspoonful of baking soda in a dry tumbler.

b. Pour three teaspoonfuls of vinegar into a tumbler of water.

c. Pour the mixture of the water and vinegar on the baking soda.

d. When the fizzing has stopped, drop apple seeds into the liquid and you will see them sink to the bottom.

e. Soon you will see each seed rise to the surface with a gas bubble that looks like a pearl. Then you will see it dive to the bottom and rise again. It will do that time after time.



18. A Flag Buoy in Fresh Water, Salt Water, and Kerosene

a. Cut a piece of candle 2 inches long. Soften one end with a lighted match and attach a piece of soda straw 4 inches long.

Slit the upper end of the soda straw and insert a paper flag 1 inch long.

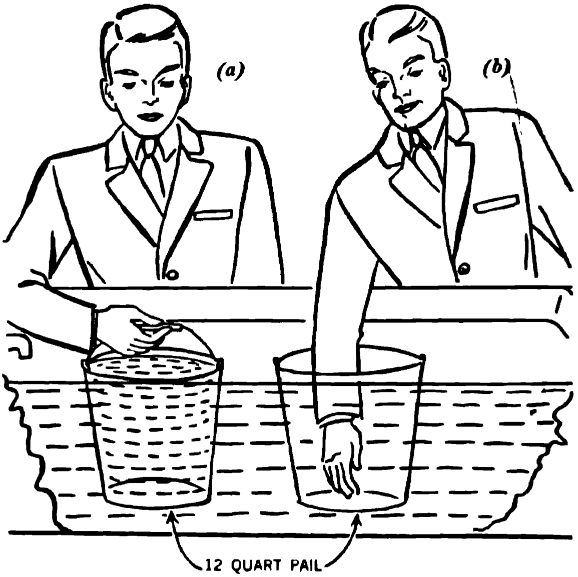
b. Fill a quart milk bottle with fresh water and stick enough tacks into the lower end of the candle to make the buoy sink in fresh water to within 1 inch of the flag.

c. Dissolve four heaping tablespoonfuls of salt in another quart milk bottle of water and put the buoy into this salt water.

The buoy will float higher in the salt water.

d. Put the buoy into a bottle of kerosene.

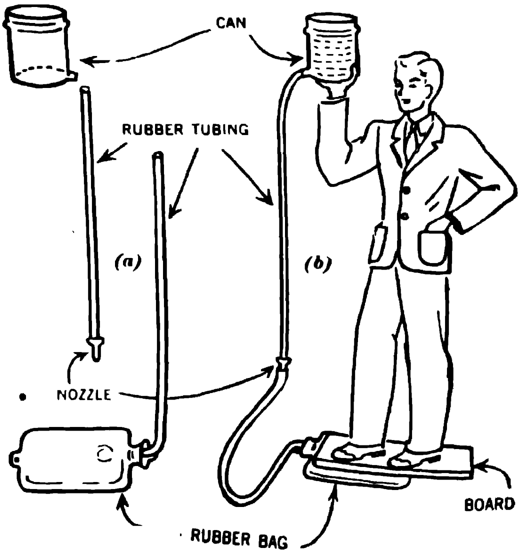
It will sink to the bottom.



19. Weight of Water and Its Buoyancy

a. Fill a bath-tub nearly full of water. Then dip a large pail into the water, filling the pail to the top, and use both hands to lift it above the water surface. Notice the force you must exert.

b. Empty the pail and sink it in water to the top. Notice that the force you must exert is about the same as that you used in *a*.

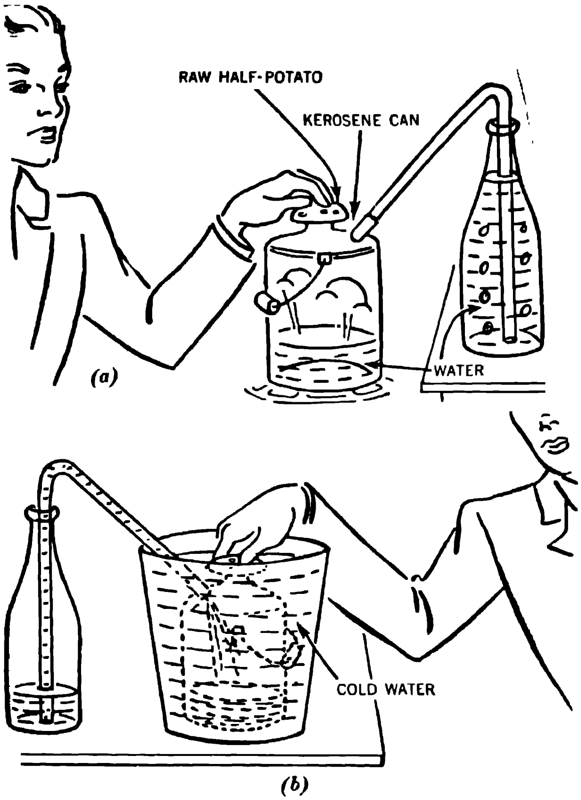


20. Up You Go

a. Find two fountain syringes, one of which has a rubber bag.

b. Stand on a short board placed on the rubber bag and connect the rubber tubes by means of a nozzle. Fill the can with water and raise it above your head. Then "up you go" until the rubber bag is full.

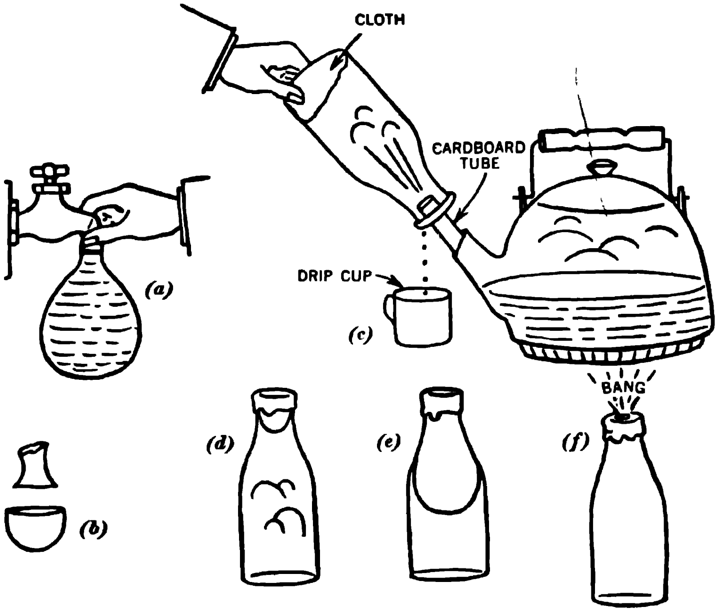
Note. Use a nozzle with a large bore so that the water will flow rapidly and lift you quickly.



21. The Oil Can Empties the Bottle

a. Separate the rubber tube from a fountain syringe, or from a bath spray, and shove one end air-tight over the spout of an empty oil can. Shove the other end down to the bottom of a quart bottle filled with water. Pour four cups of water into the can, place it on the fire, and close the top of the can air-tight with a half of a raw potato. At first air will bubble out of the end of the tube in the bottle; then steam will come out with a cracking sound.

After steam has come out for about thirty seconds, sink the can in cold water and keep its top closed air-tight. You will soon see the can empty the bottle.



22. It Bursts with a Bang

a. Fill a toy balloon with water, to stretch it.

b. Cut the balloon in two a little below its neck, as shown.

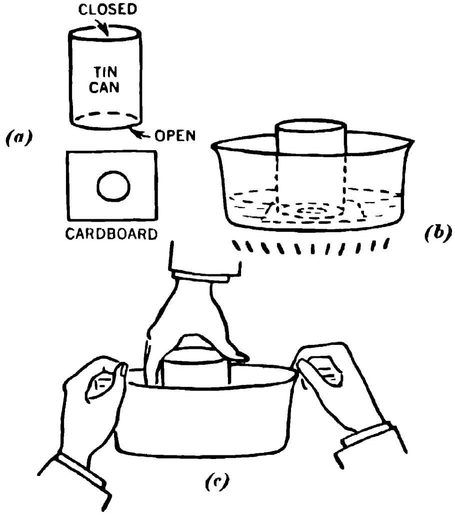
c. Run water into a tea-kettle only until it is half-way up to the spout entrance, to let steam into the spout.

If the tea-kettle spout is bigger than the mouth of the milk bottle, cut a piece of cardboard 3″ x 5″ and roll it into a tube 3 inches long. Then put one end of the tube into the spout of the tea-kettle and the other end into the mouth of a quart milk bottle. Steam the inside of the bottle one minute, then—

d. Quickly put the balloon in the mouth of the bottle and fold the edge of the balloon rubber out over the rim.

e. Soon you will see the rubber stretch down into the bottle, and—

f. Burst with a BANG.



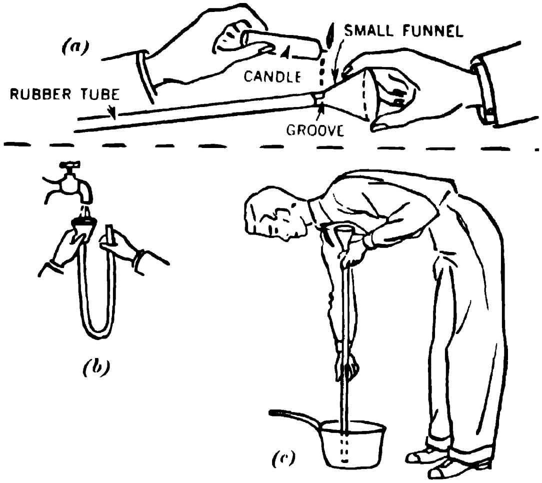
23. It's Hard to Do

a. Cut a piece of cardboard a little larger than the end of an empty food can, and cut a hole in the cardboard smaller than the end of the can.

b. Place the cardboard in a sauce-pan and put the open end of the can on the cardboard. Pour in water to a depth of about two inches. Then boil the water until the can stops rocking.

c. Let everything cool fifteen minutes or longer. Then ask a friend to hold down the sauce-pan while you try to lift the can. You will find it hard to do.

Punch a nail-hole in the closed end of the can and you will lift the can easily.



24. You Feel Suction

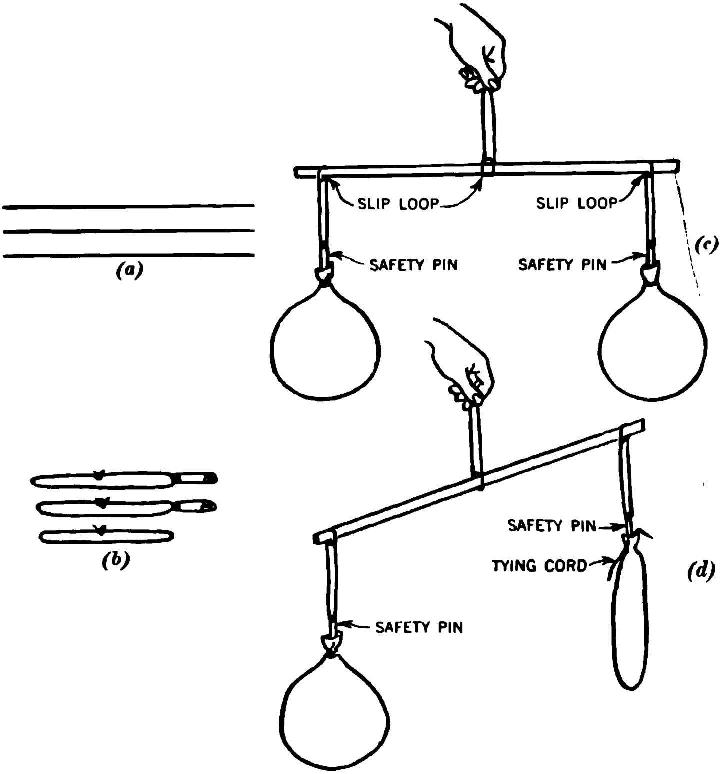
a. Examine the stem of a small household funnel and you will see a groove that lets out air when you pour liquid into a bottle through the funnel.

Take the rubber tube from a bath spray or fountain syringe. Shove one end of it over the small end of the funnel and drop melted candle wax into the groove to make it air-tight.

b. Hold the funnel and tube as shown, and fill them with water.

c. Bend over, hold the water-filled funnel against your bare chest, and lower the end of the tube into a sauce-pan. You will feel strong suction on your chest when the water flows down the tube.

Note. **In *a*, if the end of the rubber tube is stiff, put it in very hot water until it is soft.**



25. You Show That Air Has Weight

a. Cut three 15-inch lengths of string.

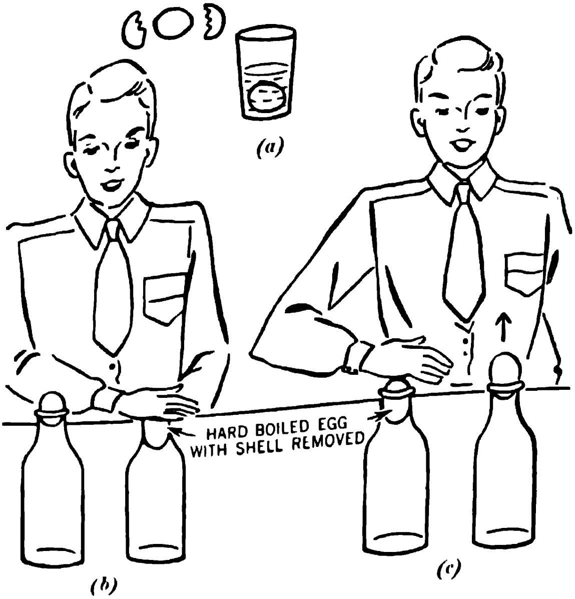
b. Pass one length through the circular spring of a safety pin, and tie it into a loop with the knot on one side.

Do the same with another length of string and another safety pin.

Make the third length into a loop with the knot on one side.

c. Blow up two large toy balloons. Tie one of them with a bowknot that can easily be untied. Use the safety pins to attach a string loop to the lip of each balloon. Use slip loops to balance the balloons on a yardstick, or other stick, as shown.

d. Untie one balloon to let out the air and hang the tying cord on it. You will see the balloon that is still full of air sink down and raise the empty balloon. This shows that air has weight.

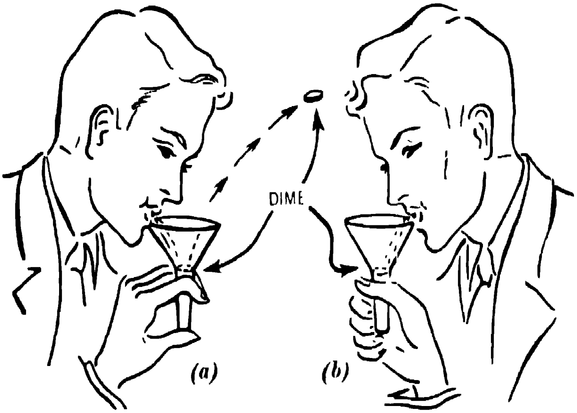

(a)
HARD BOILED EGG WITH SHELL REMOVED
(b)
(c)

26. It Bobs Up Serenely

a. Boil an egg for ten minutes or longer, remove its shell, and place the shelled egg in water to lubricate its surface.

b. Place the shelled egg in the mouth of an empty quart milk bottle and push it down into the bottle with the *palm of your hand.*

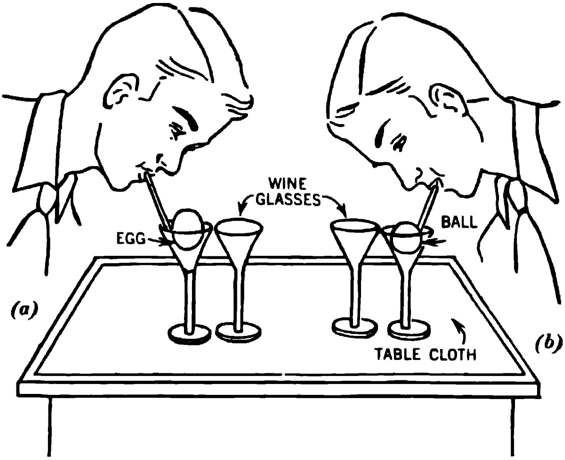
c. Lift your palm and the egg will bob up serenely.



27. You Can and You Cannot

a. Put a dime in a small funnel and close the lower end of the funnel. Blow down hard along the near inner side of the funnel and you will lift the dime easily.

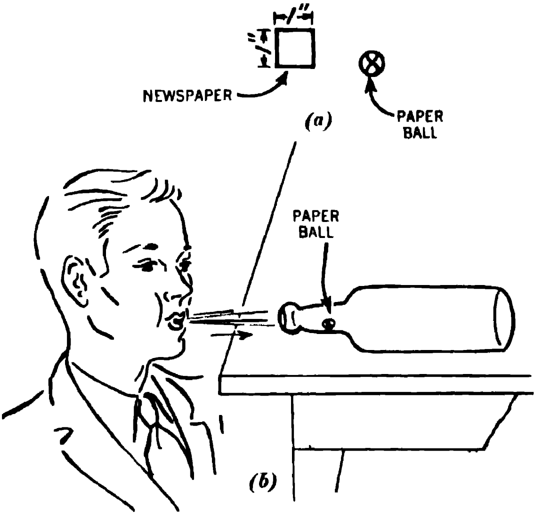
b. Repeat, with the lower end of the funnel open. You cannot lift the dime, no matter how hard you blow.



28. Practice This One

a. Stand two wine glasses rim to rim on a thick tablecloth. Then place an egg in the near glass and blow down hard between the near side of the egg and the inside of the glass. You will blow the egg over into the other glass, with a little practice. The thick tablecloth will prevent the egg from breaking if it misses the second glass.

b. Repeat with a ping-pong ball or with some other small ball.

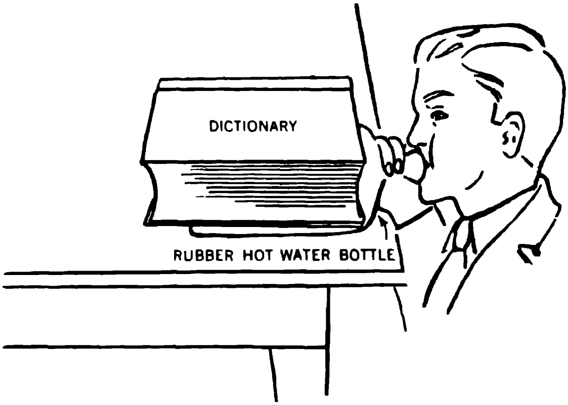


29. Surprise

a. Cut a piece of newspaper into a square about one inch by one inch. Roll it into a small tight ball.

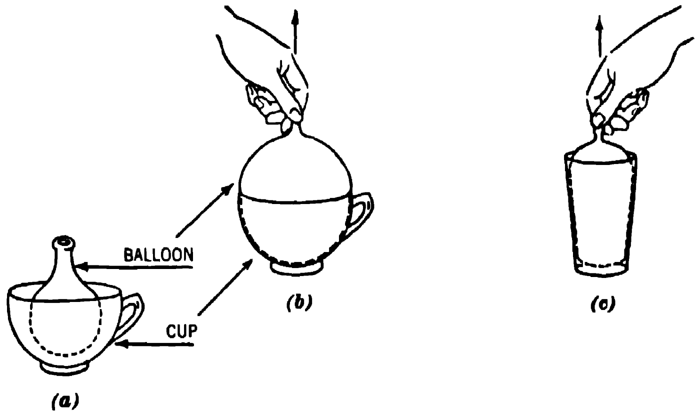
b. Lay a pop bottle on its side and shove the small paper ball about one inch into the neck.

Blow into the bottle and you will be surprised to find that you blow the ball *out of the bottle*, not into it.



30. Your Breath Lifts It

Put a large dictionary or a number of heavy books on top of a rubber hot-water bottle placed on a table. Then hold the mouth of the bag air-tight against your mouth and puff hard into the bag. Your breath will lift the book or books easily.

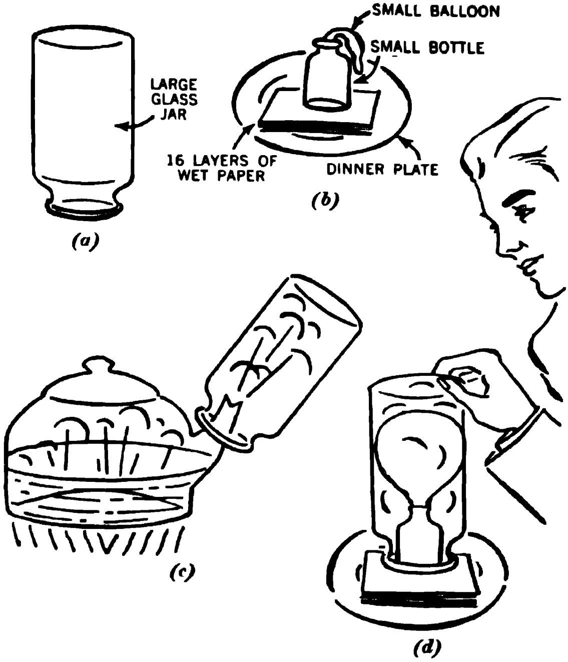


31. To Lift a Teacup or Tumbler with a Balloon

a. Hold a balloon inside a tea cup with its lower end near or touching the bottom of the cup.

b. Blow up the balloon, close it, and lift it by its neck. The balloon will support the cup.

c. Repeat *a* and *b* with a tumbler.



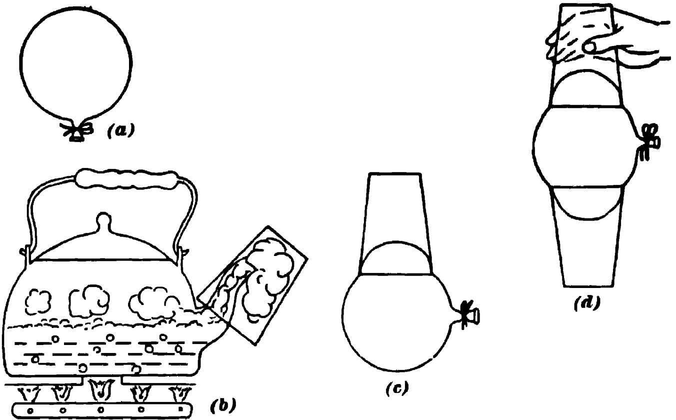
32. The Air Expands

a. Find a large glass bottle with a wide mouth.

b. Find another bottle just small enough to pass through the wide mouth of the larger bottle. Pull the mouth of a small toy balloon over the mouth of the small bottle. Fold a sheet of newspaper until it is a pad sixteen layers thick and larger than the mouth of the large bottle. Place this pad on a dinner plate and wet it thoroughly. Stand the small bottle on the middle of the wet pad.

c. Steam the inside of the large bottle for one minute, then—

d. Quickly pass its mouth over the balloon and small bottle and press it down air-tight on the wet pad. You will soon see the balloon expand.



33. Two Tumblers and a Balloon

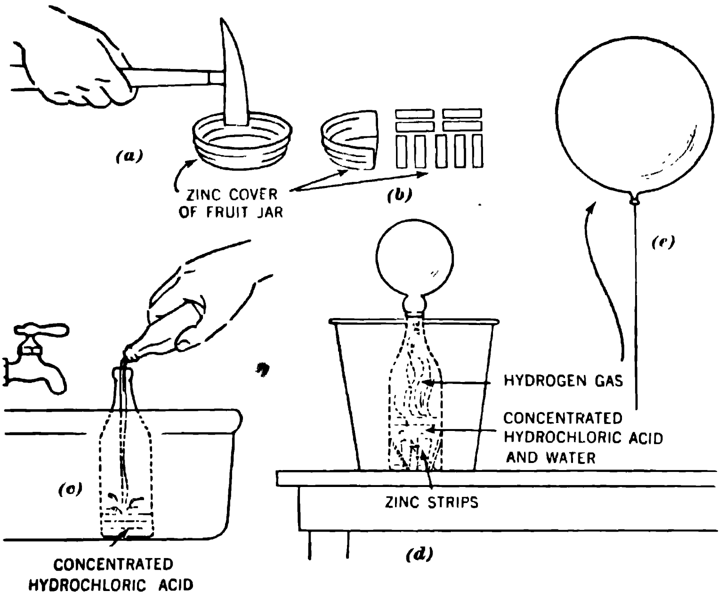
a. Blow up a large round balloon and tie it.

b. Steam the inside of a tumbler for one minute.

c. Put the tumbler quickly against the side of the balloon and hold it there until the steam condenses and the air in the balloon expands it into the tumbler.

d. Steam the inside of another tumbler for one minute and hold it against the opposite side of the balloon until the air in the balloon expands it into the tumbler. The balloon will hold the tumblers together.

Buoyancy of Gases



34. To Fill a Balloon with Hydrogen

a. Buy a five-cent zinc fruit-jar cover and break away the glass lining.

b. Cut the zinc cover in half and cut one half into strips which will go into the mouth of a pint soda bottle.

c. Buy two ounces of concentrated hydrochloric acid at a drug store and handle it with the greatest care, so that it will not burn you or your clothes.

Stand a pint soda bottle in a sink, pour into it the two ounces of concentrated hydrochloric acid, then run two ounces of water into the acid bottle and pour it into the soda bottle.

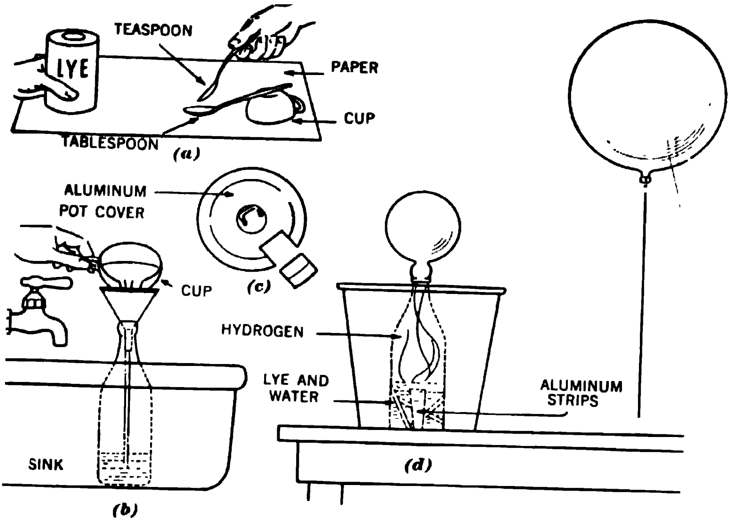
d. Stand the soda bottle in a sink or pail for safety, drop *all* of the zinc strips into the acid, and pull the wet mouth of a small one-cent balloon over the wet mouth of the bottle.

The balloon will expand.

e. After the zinc and acid have stopped producing hydrogen, tie the balloon and release it.

The balloon will float.

Warning. Do not get acid on yourself or your clothes. It will burn very badly. When you have finished rinse the bottles inside and out with plenty of water.



35. Another Way to Fill a Balloon with Hydrogen

a. Put down a piece of paper and stand on it a can of household lye and a tablespoon with its handle on an inverted cup.

Use a teaspoon to fill the tablespoon *level full* of lye.

Put the cover on the lye can at once or the lye will take water from the air.

b. Put the lye into the cup and add exactly six tablespoonfuls of water. Stand a pint soda bottle in a sink and pour the dissolved lye into the bottle. Rinse the cup and spoons, fold the paper and throw it away.

c. Cut exactly a 2″ x 2″ piece from an ***aluminum*** pot cover or baking pan. Cut it into strips small enough to go into the bottle.

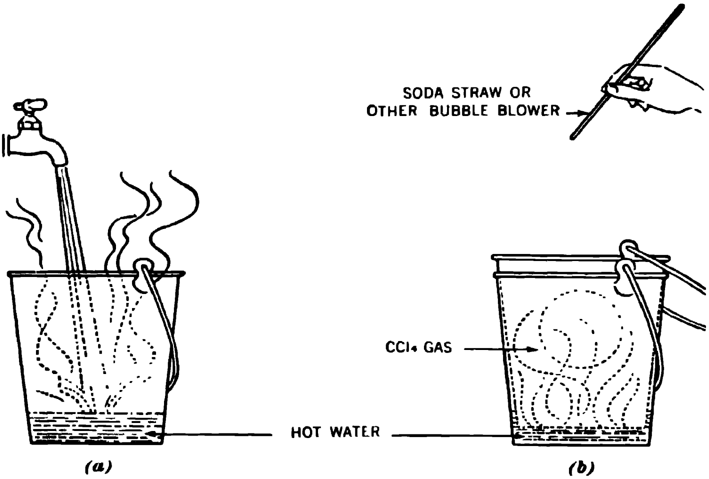
d. Stand the bottle in a pail or sink for safety, drop *all* the aluminum strips into the lye and pull the wet mouth of a small one-cent balloon over the wet mouth of the bottle.

In 30 minutes the balloon will be filled with hydrogen. Tie it and detach it.

It will rise.

Rinse out the bottle with plenty of water.

Warning. **Do not get lye on your hands or clothes. It will burn very badly.**



36. Carbon-Tetrachloride Gas

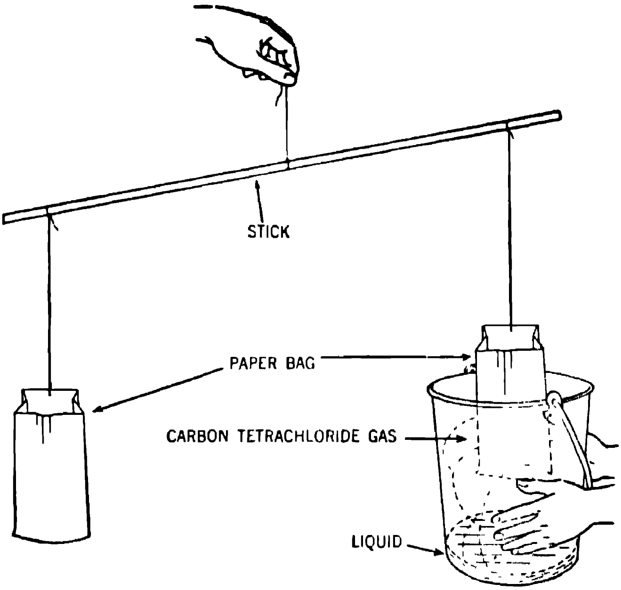
a. Pour about two quarts of *hot* water into an empty 12-quart pail.

b. Stand another empty 12-quart pail in the hot water to heat it and pour a half cup of carbon-tetrachloride liquid into the warm pail; wait about five minutes for the warmed liquid to form a gas; then blow a large soap bubble and drop it into the pail.

The soap bubble will float in the carbon-tetrachloride gas.

Carbon-tetrachloride (CCl_4) is a cleaning fluid which does not burn. It can be bought at a drug store for forty cents a can.

If you have only one large pail, turn it upside down in a sink and pour very hot water over it to warm it. Then turn it right side up and pour in the carbon-tetrachloride liquid.



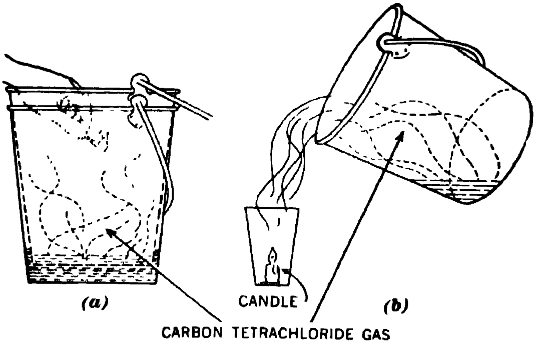
37. Another Demonstration of Gas Buoyancy

Balance a yardstick or other stick. Hang on it two paper bags of the same size and balance them.

Let one experimenter hold the paper bag balance while another *lifts* the pail of CCl_4 gas up under one bag.

The carbon-tetrachloride gas will lift the bag.

Note. **Do not let the bag touch the liquid.**



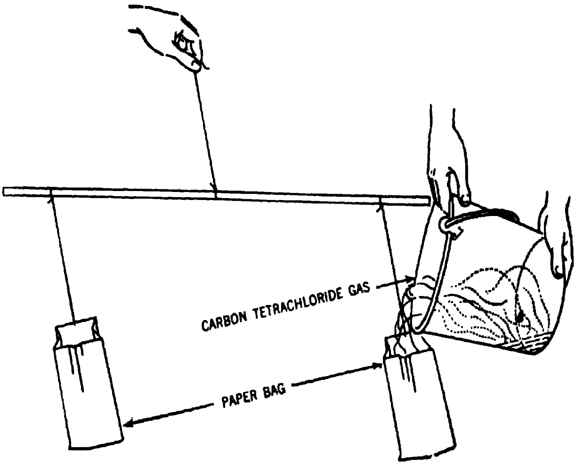
38. The Gas Pours and Puts Out Fire

a. Light a match and move it down slowly into the carbon-tetrachloride gas.

The gas will put out the fire.

b. Place a *short* piece of candle in a tumbler and light it, then tilt the pail over the tumbler to let the gas pour, but not the liquid.

The gas will pour as though it were a liquid, and extinguish the candle.

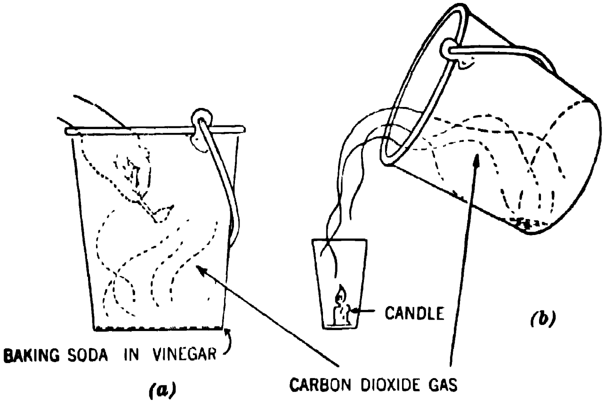


39. The Gas is Heavier than Air

Let one experimenter hold the paper bag balance and one bag, while another fills the other bag with carbon-tetrachloride gas.

The filled bag will sink when released.

Pour the liquid carbon-tetrachloride back into its can, to save it.



40. Carbon-Dioxide Gas

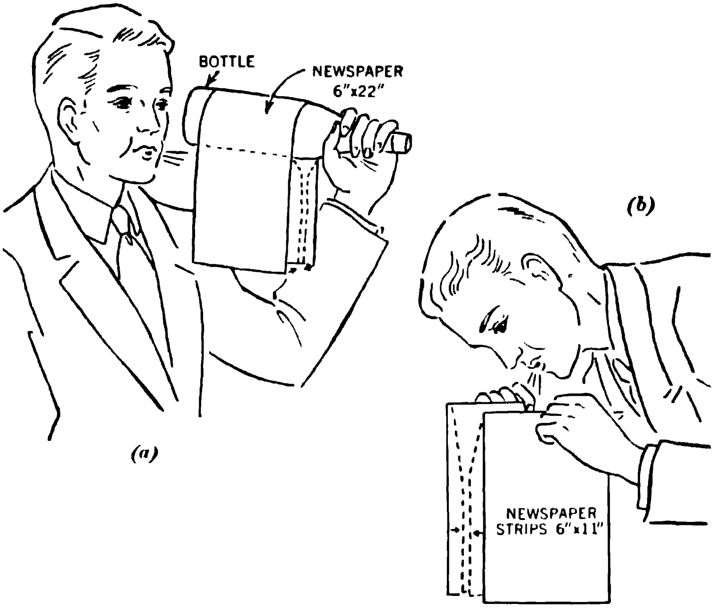
a. Pour a half tumbler of vinegar into a 12-quart pail and add two level tablespoonfuls of baking soda.

They will fizz and produce carbon-dioxide gas.

Lower a lighted match into the gas and it will go out.

b. Tilt the pail over a tumbler containing a *short* lighted candle.

The gas will pour and extinguish the candle.

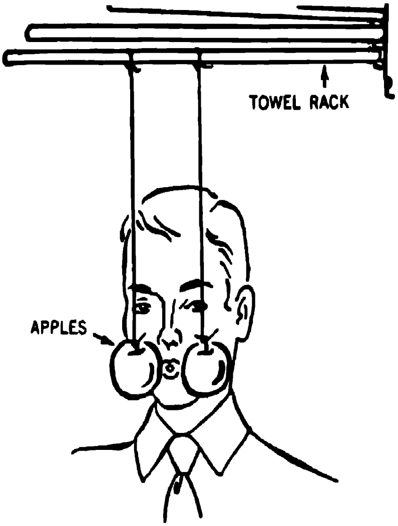


41. You Blow Them Together, Not Apart

a. Cut a strip of newspaper about 6" x 22", curve it over a bottle, and blow under the bottle between the newspaper halves.

You will blow the halves *together*, not apart.

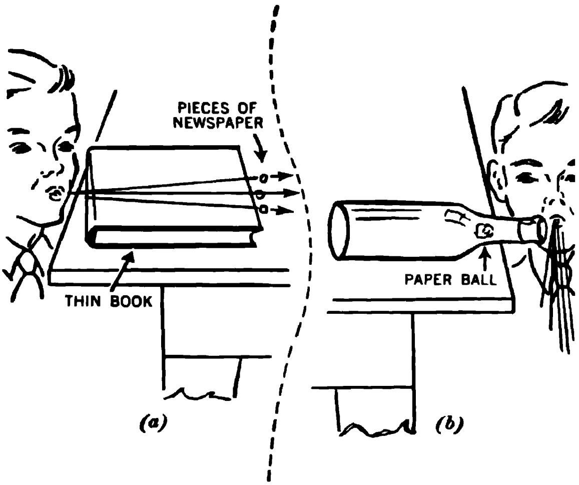
b. Tear the newspaper strip into two pieces 6" x 11", hold them about 4 inches apart below your mouth, and blow down between them. Again you will blow the strips together, not apart.



42. Your Air Stream Makes Them Bump

Hang two apples about one inch apart from a kitchen towel rack or other support. Blow hard between them.

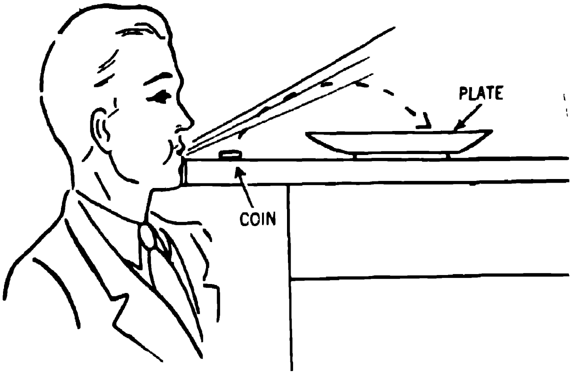
You will see your rapid air stream make the apples bump together.



43. The Paper and Ball Move Toward Your Air Stream

a. Cut a 1″ x 1″ square of newspaper and tear it into four or five pieces. Lay the pieces on the table behind a *thin* book and close to the edge of the lower book cover. Blow hard over the book and you will see the paper pieces rise into your air stream and fly away with it.

b. Cut a 1″ x 1″ square of newspaper and roll it into a small ball, between your palms. Put this ball in the neck of an empty bottle and blow across the mouth of the bottle, at a small angle away from the mouth. You will see the ball move toward your air stream and fly away with it.

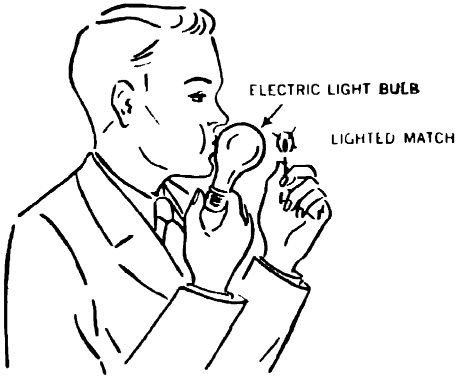


44. You Lift the Dime with Air

Place a dime on the table with its center 2 inches from the edge. Behind the dime place a dinner plate with its middle 1 foot from the edge. Sit on the floor with your lips about ½ inch above the edge of the table and blow *hard* over the dime *toward a point about 6 inches above the middle of the plate.*

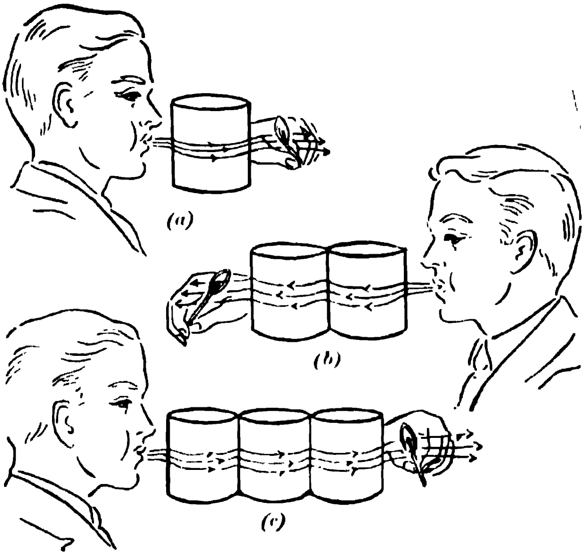
You will see the dime rise up into your air stream and fly with it into the plate or over it.

Note. You must blow *hard.*



45. You Appear to Blow Through a Lamp Bulb

Hold a lamp bulb against your lips and hold a lighted match one or two inches behind the bulb. Blow hard against the bulb and you will blow out the match.



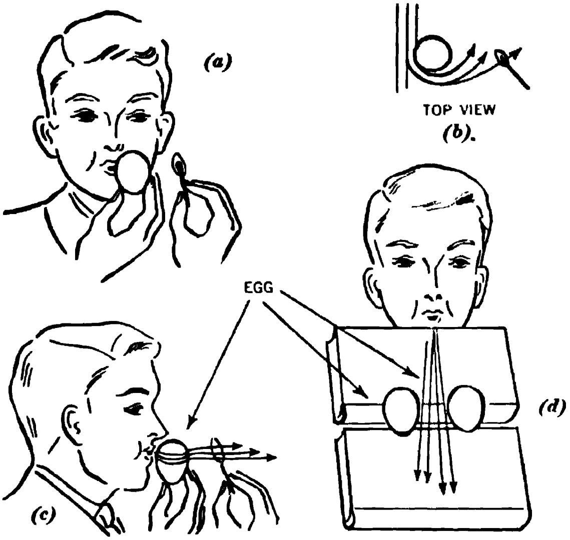
46. You Appear to Blow Through the Cans

a. Take a small can about the size used for soup. Stand it on the table. Place your mouth about 2 inches in front of the can and hold a lighted match about 2 inches behind the can. Blow hard against the can and you will blow out the match.

b. Repeat with two cans in a row.

c. Repeat with three cans in a row.

In each case you will blow out the match.



47. Fun with Eggs

a. Hold one side of an egg opposite the middle of your mouth and hold a lighted match about 2 inches from the opposite side. Blow straight ahead and—

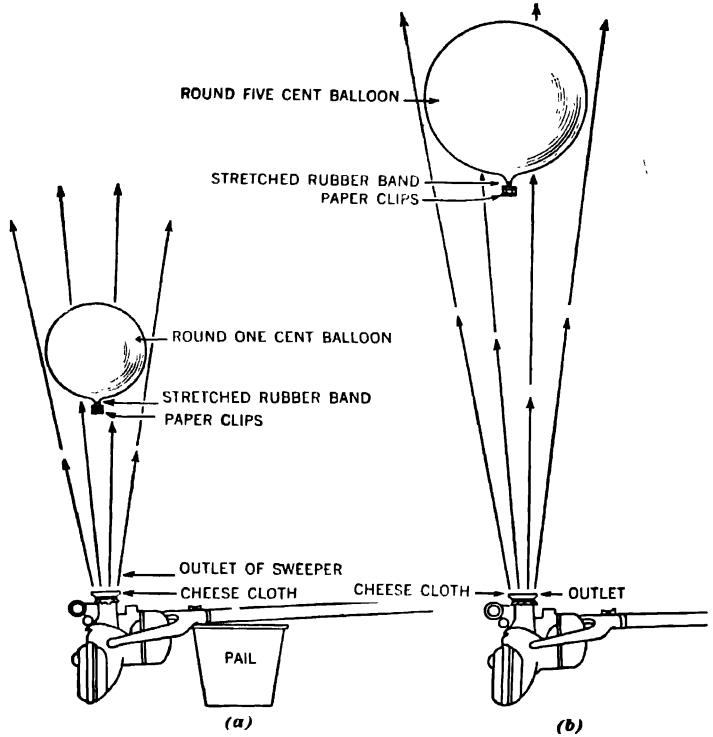
b. That part of your air stream which is near or touching the egg will curve around the egg and blow out the match.

c. Place your lips against one side of an egg and hold a lighted match about 2 inches from the opposite side.

Blow against the egg and you will blow out the match.

d. Place two similar books about 1 inch apart on the table and place two eggs parallel and 1 inch apart on the slot between the books.

Blow hard between the eggs and you will blow them *together*, not apart.



48. The Air Stream Supports and Holds the Balloons

a. Remove the bag from a vacuum sweeper. Support the sweeper on a table in such position that the outlet points vertically upward. Fasten a 6″ x 6″ piece of cheesecloth over the outlet by means of a doubled rubber band, to make the air stream uniform.

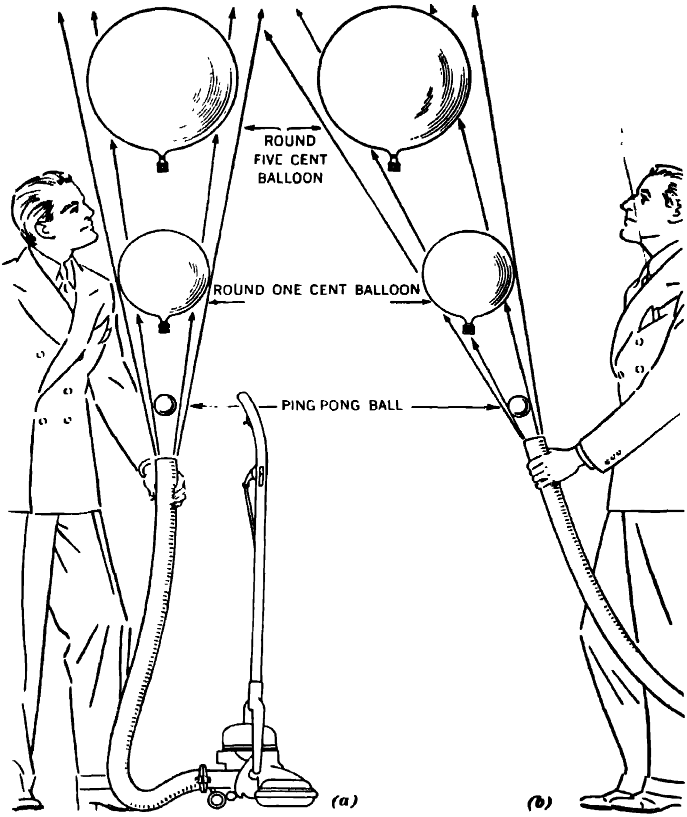
Blow up a *round* one-cent balloon until it has a volume of about one quart and tie it. Place it in the air stream of the vacuum sweeper and attach paper clips as weights until it floats about 2 or 3 feet above the outlet.

The air stream will cling to the balloon and keep it bobbing up and down.

Tilt the sweeper slowly.

The balloon will remain bobbing in the air stream until the angle is 10° or 15° from the vertical.

b. Repeat with a five-cent balloon blown up until it is very large.



49. The Air Stream Takes the Ball and Balloons for a Walk

a. Remove the cheesecloth from the outlet of the vacuum sweeper and attach the hose without cheesecloth or nozzle.

Start the motor and let one experimenter hold the end of the hose pointing vertically upward while another puts into the air stream a ping-pong ball, the small balloon, and the large balloon, one after another.

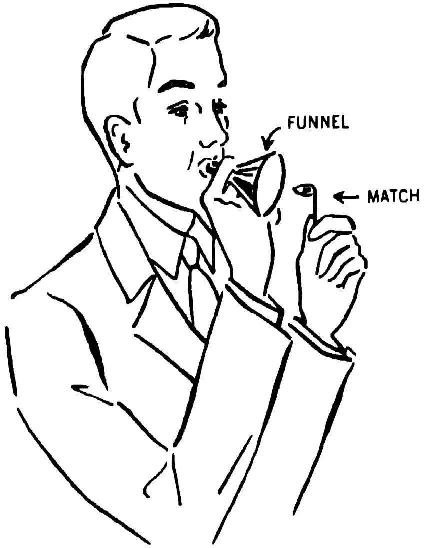
They will bob up and down together one above another.

Let the first experimenter walk around slowly while keeping the air stream vertical.

The ball and balloons will remain in the air stream.

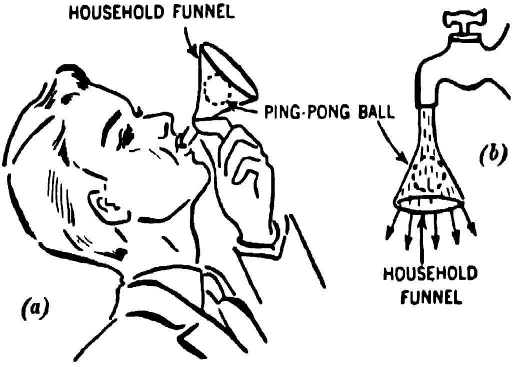
b. Let the first experimenter tilt the air stream slowly.

The ball and balloons will remain in the air stream until the angle is about 10° to 15°.



50. An Air Stream in a Funnel

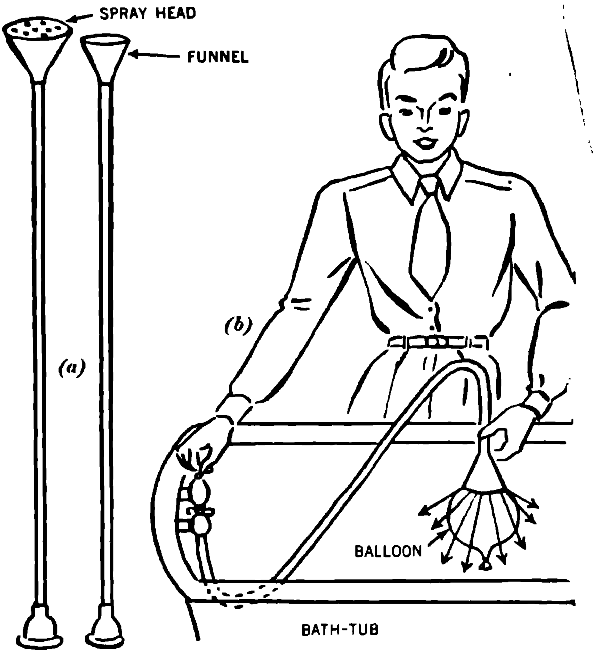
Blow into the small end of a funnel, with a lighted match opposite the *middle* of the funnel top, and you will blow the flame *toward you.* But if you hold the lighted match opposite the *rim* of the funnel top, you will blow the flame *away from you.*



51. A Ball in a Funnel

a. Place a ping-pong ball in a household funnel. Then point the large end of the funnel upward and try to blow the ball out. You will find that the harder you blow the more firmly the ball clings to the funnel.

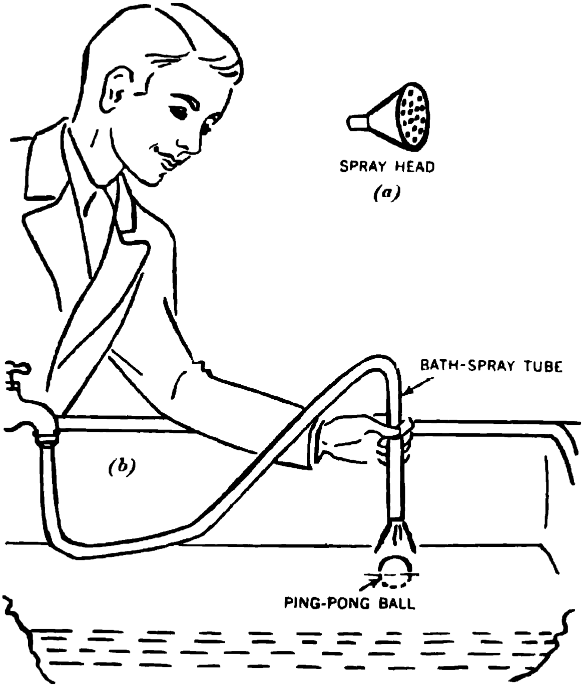
b. Hold the ball in the funnel. Then shove the stem of the funnel into a faucet and turn on the water. You will see the water stream hold the ball in the funnel, against its own downward force and against the downward pull of gravity on the ball.



52. A Balloon in a Funnel

a. Remove the spray head from a bath spray and replace it with a household funnel.

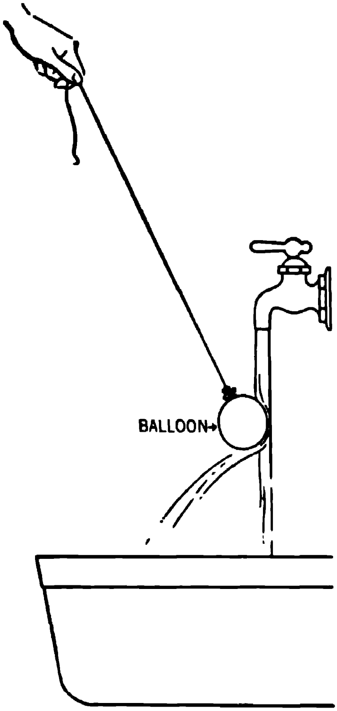
b. Blow up a toy balloon and tie it. Attach the rubber tube of the spray to a faucet. Hold the balloon in the vertical funnel and turn on the water. You will see the water stream hold the balloon against the funnel mouth. The more rapid the stream, the tighter it will hold the balloon.



53. A Ball in a Water Stream

a. Separate the spray-head from a bath spray.

b. Run water into a bath-tub to a depth of two or three inches. Attach the rubber tube of the spray to the faucet. Float a ping-pong ball on the water and shoot a *vertical* stream of water down on the ball. Move the vertical stream around in all directions and you will see it take the ball with it.

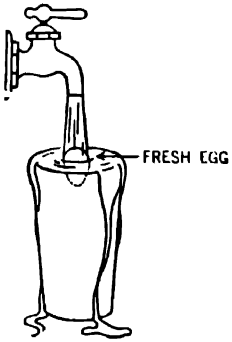


54. The Water Stream Clings to the Balloon

Blow up a balloon and tie it with a cord about 3 feet long. Swing the balloon as a pendulum and let it strike the water stream from a faucet.

The water stream will hold the balloon and part of it will curve under the balloon.

You will feel the pull of the water.

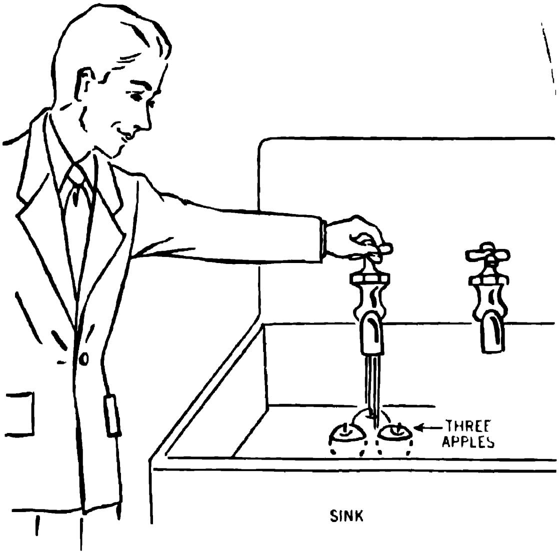


55. The Water Stream Lifts the Egg

Place a fresh egg in a tumbler of water and it will sink to the bottom.

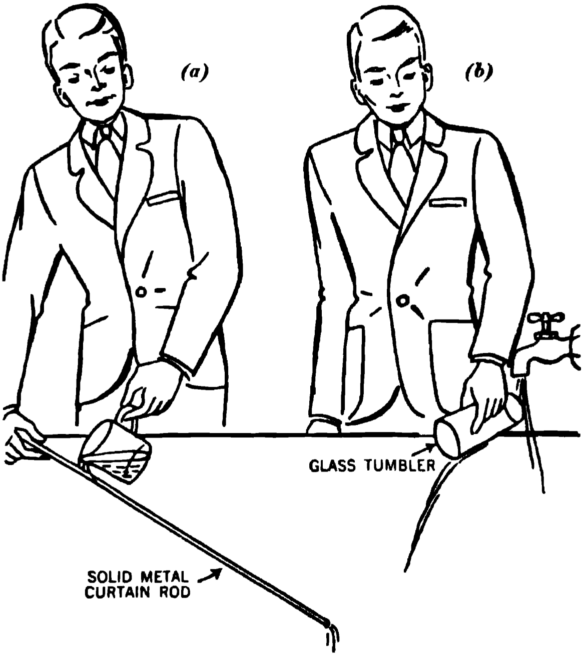
Place the tumbler and egg under a water faucet and gradually turn on the water more and more.

When the water stream has more than a certain velocity it will lift the egg up against the force of the stream and apparently try to lift it out of the tumbler. The rapid flow of water will also keep the egg in the middle of the stream.



56. The Water Stream Holds Them Together

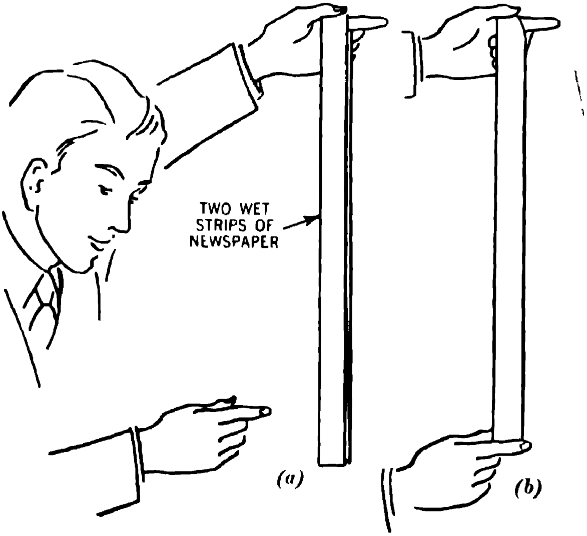
Float three apples, close together, on water in a sink or wash bowl. Move the apples until the water stream from a faucet falls in the open space between them. You will see the water stream hold them together.



57. The Water Clings

a. Hold the solid metal part of a curtain rod at an angle, as shown, and pour water gently on the top end. You will see water cling to the rod and flow along it to the end.

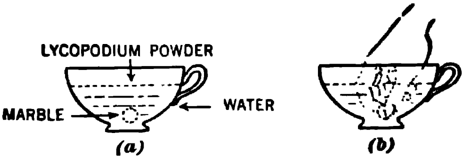
b. Hold the *bottom* of a glass tumbler in the stream from a faucet and incline the top of the tumbler downward. You will see the water cling to the under side and appear to flow from *inside* the tumbler.


TWO WET STRIPS OF NEWSPAPER
(a)
(b)

58. The Water Surfaces Pull Them Together

a. Cut two strips of newspaper 22″ x 2″. Wet them thoroughly and hang them up on opposite sides of a forefinger so that the flat sides face each other, about ¾ inch apart, but do not touch.

b. Bring the flat sides together at the bottom and *instantly* the water surfaces will pull the strips together to a point just below your forefinger.

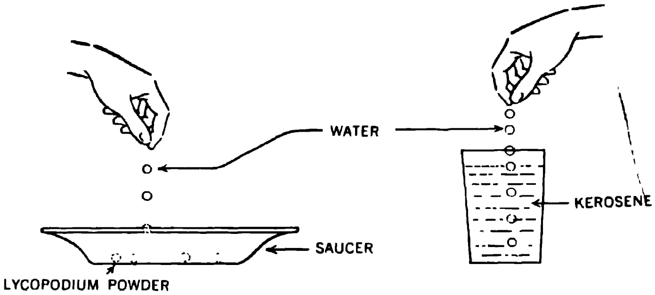


59. To Lift a Marble out of Water without Wetting Your Fingers

a. Place a marble in a teacup, cover it with ¼ to ½ inch of water and sprinkle lycopodium powder over the water to a thickness of about $\frac{1}{16}$ inch. Use plenty.

b. Lift out the marble. Your fingers and thumb will be covered with a layer of powder but they will be dry.

Note. You can buy sufficient lycopodium powder at a drug store for five cents.



(a) *(b)*

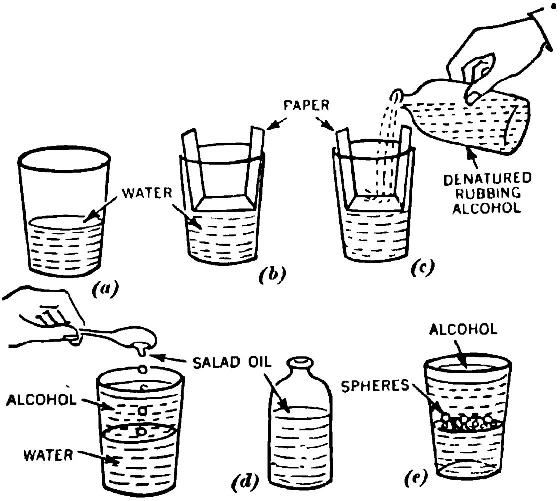
60. Water Spheres

a. Sprinkle lycopodium powder over the inside of a saucer to a depth of about 1/32 inch and sprinkle water drops from the fingers into the saucer.

The drops will form water spheres which will run about in a lively manner when you tilt the saucer.

b. Fill a tumbler with kerosene and shake water drops into it from your fingers.

The small water drops will remain spherical as they sink through the kerosene.



61. A Miniature Solar System

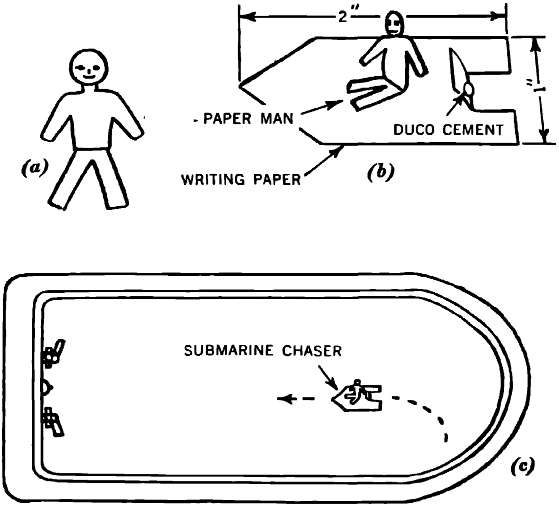
a. Fill a tumbler half full of water.

b. Bend an 8″ x 2″ piece of paper down on the water surface.

c. Fill the tumbler with denatured rubbing alcohol. Then lift out the paper slowly to avoid mixing the liquids too much.

d. Add a half teaspoonful of salad oil slowly, and—

e. You will see the oil in the shape of perfect spheres. They will look like a miniature solar system.

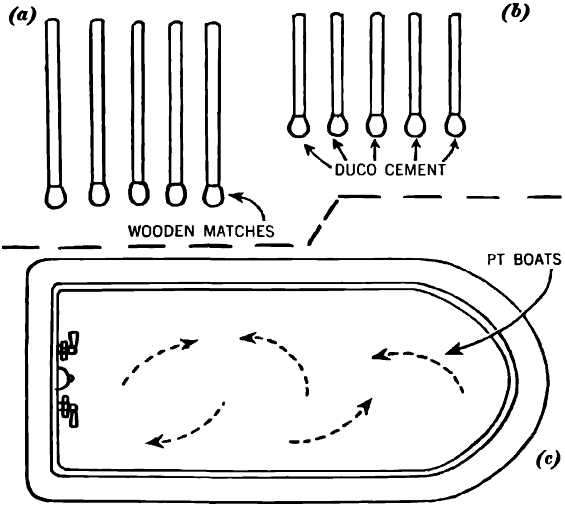


62. Submarine Chaser

a. Draw on paper a little man about 1 inch tall and cut him out.

b. Cut out of heavy writing paper or light cardboard a boat about 2 inches long and 1 inch wide. Cut a notch about ½ inch wide and ¼ inch deep at the stern of the boat. Bend up the cut paper or cardboard and cover its rear surface with Duco cement in such a way that the cement will touch the water. Seat the little man on the boat and glue him there.

c. Run water into a bath-tub until it is about 1 inch deep. Wait until the surface of the water is quiet. Then float the boat and you will see it dash about for two or three minutes. It will appear to be chasing an enemy submarine.

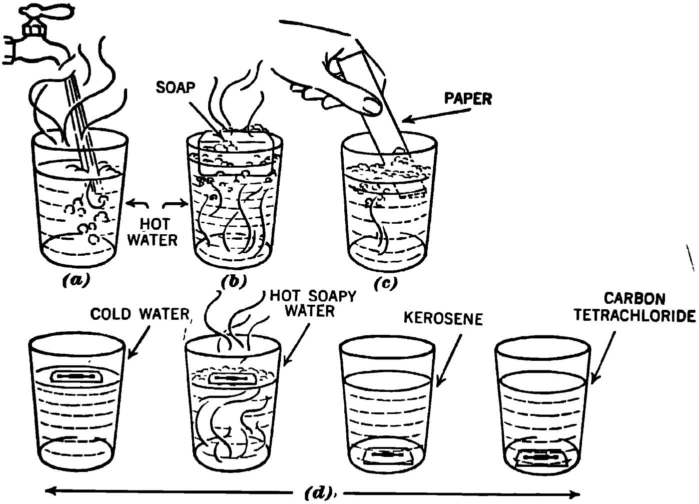


63. Patrol Torpedo Boats

a. Take five large wooden matches and break off the head of each.

b. Dip the broken end of each match in Duco cement.

c. Empty out the water used in Experience 62 and run fresh water into the bath-tub to a depth of about one inch. When the water surface is still, float the five matches, and you will see them dash about in a lively manner for two or three minutes. They act like patrol torpedo boats looking for enemy warships.



64. Liquid Surfaces, Strong and Weak

a. Fill a tall tumbler to within 1 inch of the top with *hot* water.

b. Place a piece of soap in the hot water for one minute or more.

c. Lift out the soap and remove the bubbles from the surface with a piece of paper.

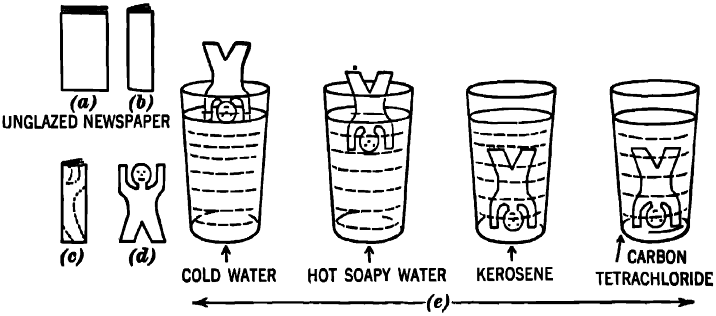
d. Stand in a row four tumblers filled to the same height respectively, with cold water, hot soapy water, kerosene, and carbon-tetrachloride.

Drop a safety razor blade from a height of about one-fourth inch flat on the surface of each.

The blade will float on the cold water and possibly on the hot soapy water, but it will sink instantly in the kerosene and carbon-tetrachloride.

Rock gently the two tumblers in which the blades are floating. The blade in the hot soapy water will sink first.

Keep the liquids for the next experience.



65. Divers and Liquids

a. Cut four pieces of unglazed newspaper 3″ x 2″.

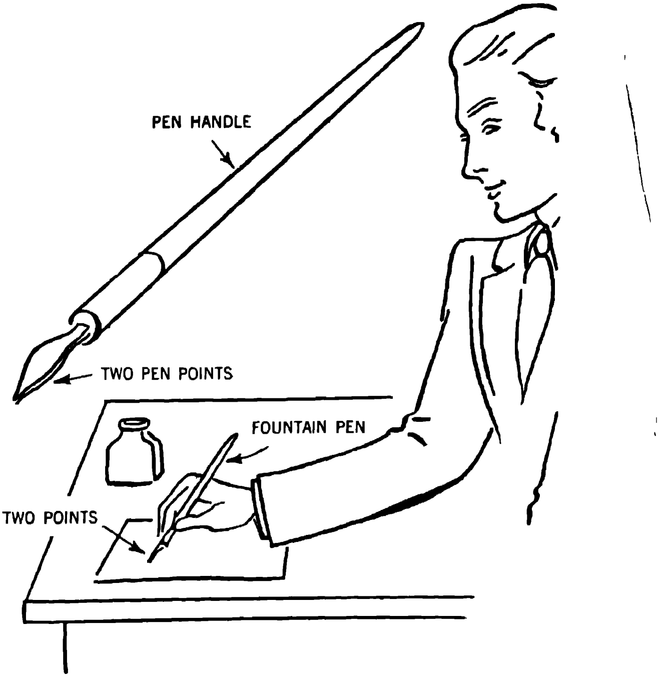
b. Fold them lengthwise.

c. Cut out as indicated.

d. Put in eyes, nose, and mouth and you have four divers.

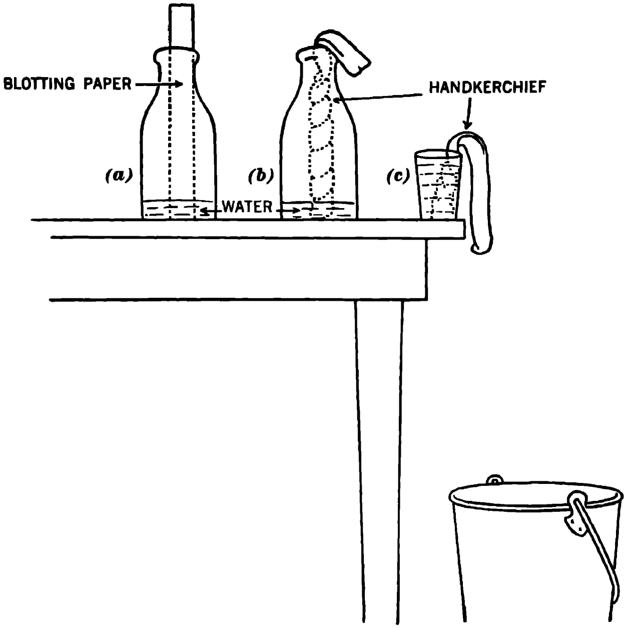
e. Drop one head-first into each liquid from a height of about ½ inch.

The diver in cold water will sink very slowly; the one in hot soapy water, more rapidly; and those in kerosene and carbon-tetrachloride, instantly.



66. You Make a Fountain Pen

Put *two* pen points in a holder as shown, and you will have a fountain pen which will write much longer, after each dip, than a holder with a single pen point.



67. Capillarity

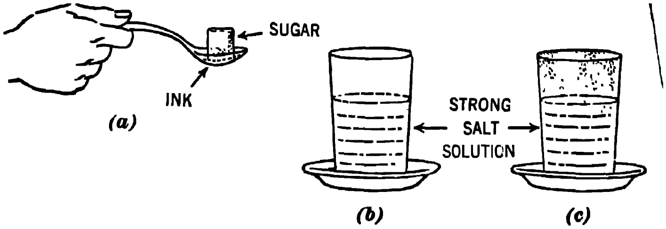
a. Stand a strip of blotting paper in an inch of water in a quart milk bottle.

b. Hang a twisted handkerchief in another quart milk bottle, with its lower end dipping into one inch of water.

Examine them after an hour and you will find that water has risen into each to a considerable height.

c. Arrange a handkerchief so that one end is at the bottom of a full tumbler inside and the other *below* the bottom outside.

The handkerchief will empty the tumbler over night.



68. Capillarity

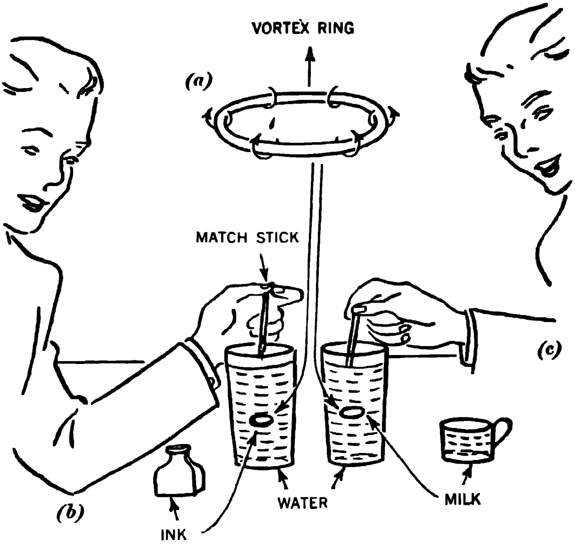
a. Place a lump of sugar in a half-teaspoonful of ink.

The ink will rise rapidly in the sugar.

b. Boil a half-tumblerful of water in a sauce-pan and add to it all the table salt it will dissolve and a little more.

When the solution is lukewarm, pour it into a tumbler, place the tumbler in a saucer, and stand it aside for a month or more.

c. The salt will gradually crawl up the inside of the tumbler and down the outside.



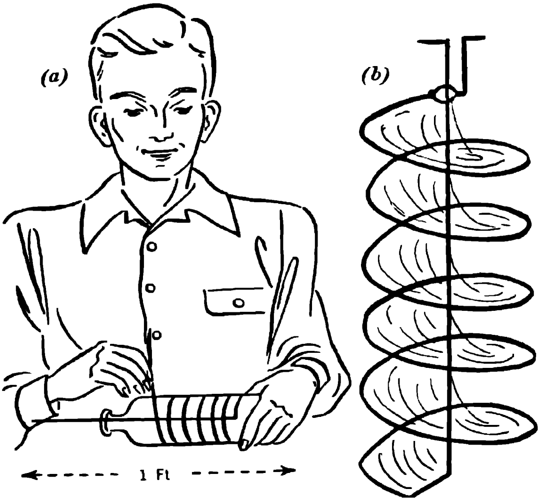
69. You Make Vortex Rings

a. A vortex ring revolves, as shown, and expands.

b. Fill a tall tumbler with water. Wait until the water is still. Then dip the butt end of a wooden match stick in ink and touch it to the water surface. You will see the ink make a beautiful descending vortex ring. Notice that the ring revolves and expands, and sometimes breaks up into beautiful small vortex rings.

c. Repeat the test in fresh water with a fresh match stick and milk (not cream) and you will get similar results.

d. Repeat *b* and *c* in fresh water but drop the ink and milk from a height of one to four inches. Sometimes you will see the vortex ring sink to the bottom ***and bounce***.

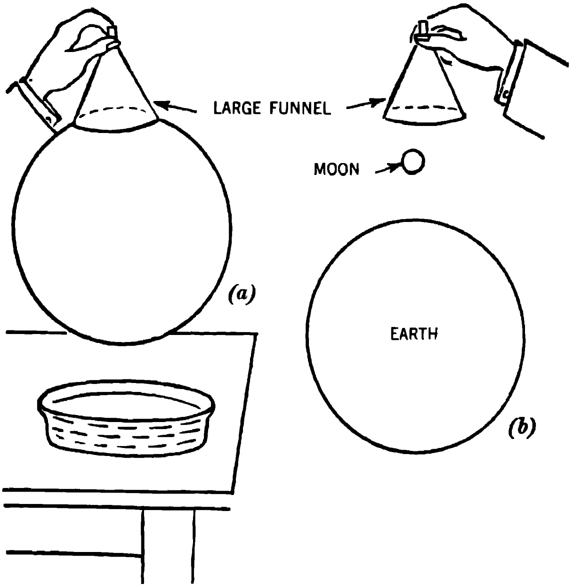


70. You Make a Spiral Ramp

a. Make a spiral out of wire about the size of the lead in a lead pencil, in this way: Cut a length of wire about 4 feet long. Lay 1 foot of the wire along a round bottle about 1¾ inches in diameter. Hold the 1 foot of wire at the bottom of the bottle and wind six turns over it and around the bottle. Shove the top of the 1-foot wire through a loop at the top of the spiral and bend both ends at right angles, as shown in *b.*

You need a strong soap solution for this experience and the next two. Make it in this way: Put two level tablespoonfuls of soap powder into a quart milk bottle, fill the bottle with hot water, shake it, and let it stand over night.

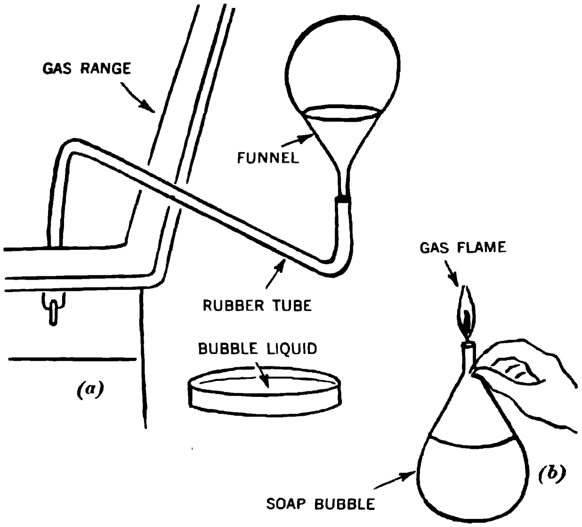
b. To make the spiral ramp, pour the soap solution into an empty food can, compress the spiral, dip it under the solution, lift it out while it is still compressed, and expand it slowly. The soap film will be a cylinder at first, but it will soon take the shape of a beautiful spiral ramp.



71. Earth and Moon Bubbles

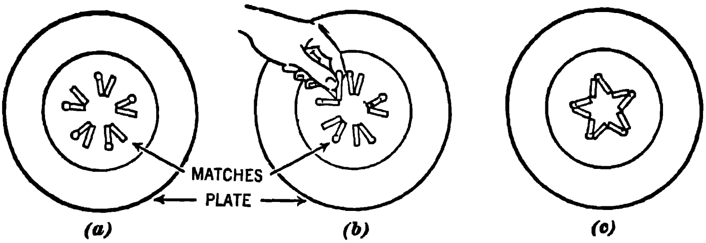
a. Dip the large end of a large household funnel in bubble liquid. Lift it out, one edge first, and you will get a film over the large end. Blow a large bubble.

b. Detach the large bubble (the earth) and frequently you will see also a small bubble (the moon).



72. A Fire Bubble

Make the soap solution of Experiences 70 and 71 or buy a bottle of bubble liquid at the ten-cent store. Pour the bubble liquid into a saucer to a depth of $\frac{1}{2}$ inch. Remove the top grate from a gas range and lift out one burner. Slide over the spud of the burner one end of the rubber tube from a bath spray or fountain syringe. Slide the other end of the rubber tube over the stem of a small household funnel. Dip the large end of the funnel in and out of the bubble liquid. Turn on the gas, to blow a bubble about 3 inches in diameter. Shut off the gas. Detach the funnel and hold a finger over its small end. Light a match, remove your finger, and light the gas. You will see the bubble contract and drive the gas out of the funnel.

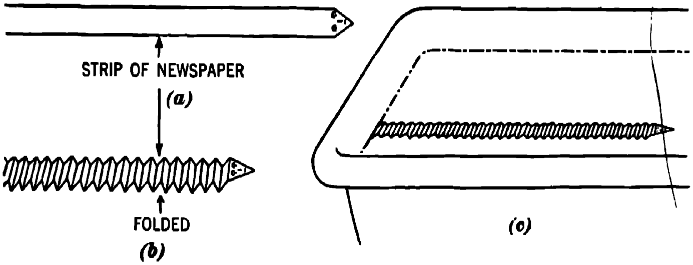


73. A Five-Pointed Star

a. Break five matches half through at the middle and arrange them symmetrically on a dry plate around a circle about $\frac{3}{4}$ inch in diameter.

b. Dip a sixth match into water and wet each break with a drop or two of water.

c. The matches will form a five-pointed star.



74. A Sea Serpent

a. Cut a 2-inch strip of unglazed newspaper across the full width of the double page.

Make a serpent head with eyes and nose.

b. Fold it back and forth each half inch to make a zig-zag.

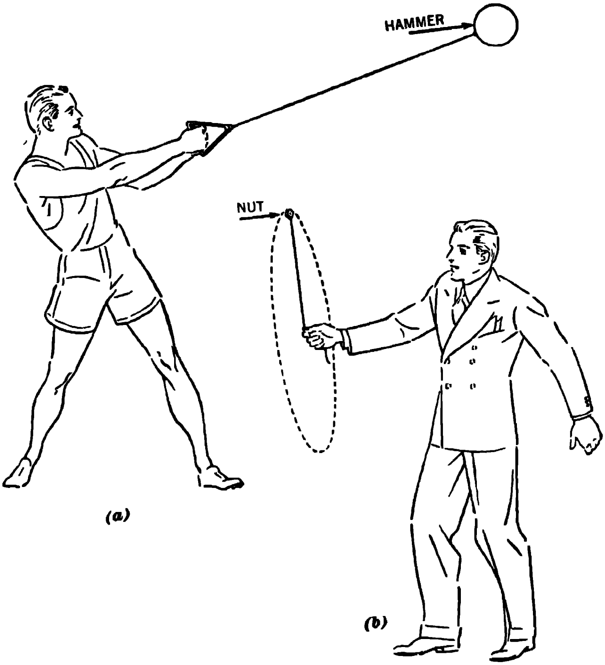
c. Fold it tight, place its tail against one side of a bath-tub and release it on water.

The serpent will stretch out quickly across the tub.

d. Make another sea serpent and put it in the bath-tub *on its side.*

It will squirm about in a very realistic manner.

Centrifugal Force



75. You Feel Centrifugal Force

a. *Centrifugal force and the hammer throw.*

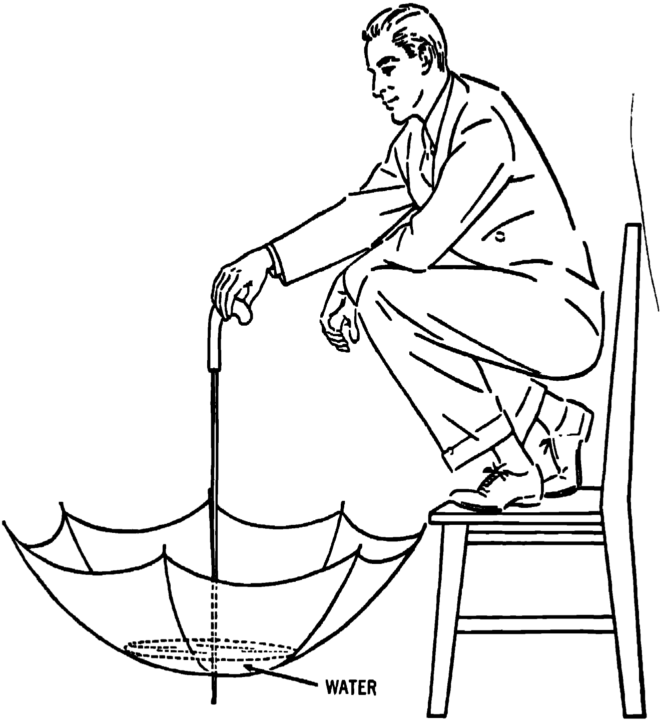
Turn two or three times rapidly to give the hammer high speed.

The centrifugal force on your hands and arms will be very great.

b. *Centrifugal force with a light weight.*

Tie an iron nut or other light weight to the end of a *stout* cord and whirl it in a circle.

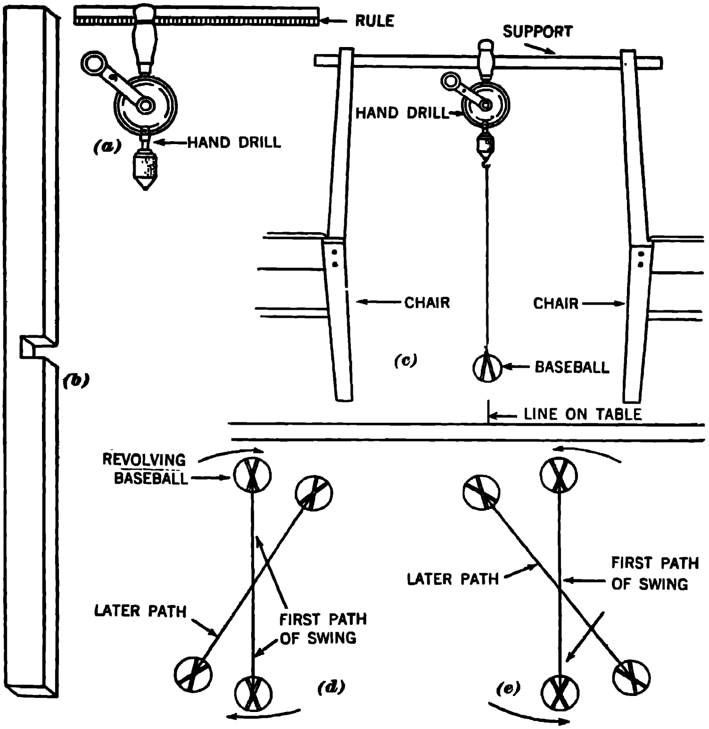
The greater the weight and the faster it moves, the greater will be the centrifugal force with which it pulls away from your hand.



76. Centrifugal Force with an Umbrella

Open an umbrella, pour a tumbler of water into it, stand on a chair, and twirl the umbrella.

You will see the water fly out over the edge and make a circle on the floor.



77. Another Demonstration of the Sidewise Shift of a Revolving Baseball

a. Find a hand drill and measure the width of its handle.

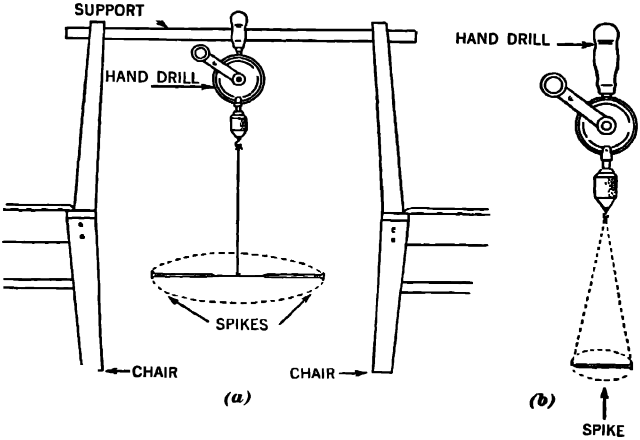
b. Find a soft wood board about 4′ x 2½″ x 1″ and at its middle cut a slot about $\frac{1}{16}$ inch narrower than the width of the drill handle.

c. Drive the handle into the slot and support the hand drill between two chairs on a table. Fasten in the chuck a small screw-eye (18 for 5 cents). Attach one end of a *light* cord to the eye and the other end to a rubber band stretched around a baseball. Make the length of the cord such that the ball is about 2 inches above the table. Draw a line on the table, swing the baseball as a pendulum above this line, and turn the drill.

d. The baseball will "follow its front" as in Experience 4.

Turn the drill handle clockwise and the path will shift in the direction shown.

e. Turn the handle counter-clockwise and the path will shift in the opposite direction.



78. Centrifugal Force with Spikes

a. Fasten the point of each of two similar spikes to a 6-inch cord. Tie one end of a *light* string to the middle of the 6-inch cord and the other end to a screw-eye. Make the length of the string such that the heads of the spikes will be about 2 inches above the table when the screw-eye is in the chuck of the hand drill. Fasten the screw-eye in the chuck and turn the drill.

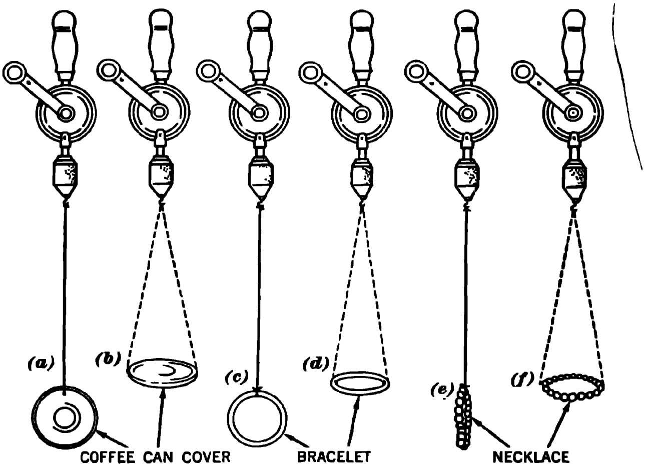
The spikes will rise until they revolve in a horizontal plane.

b. Suspend a single spike from a light string and screw-eye.

Fasten the screw-eye in the chuck and turn the drill.

The spike will rise and revolve in a horizontal plane.

Why? See page 242



79. Centrifugal Force with a Coffee Can Cover, Bracelet, and Necklace

a. Punch a nail hole near the edge of a coffee can cover and support the cover as shown.

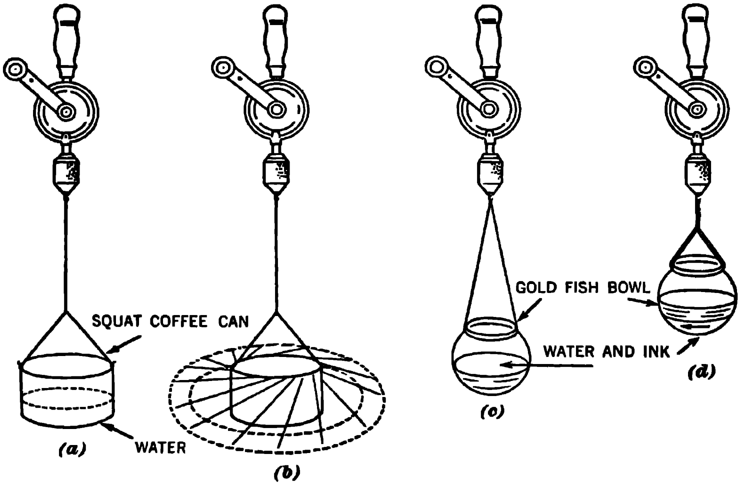
b. Turn the drill and you will see the cover rise and revolve in a horizontal plane.

c. Support a bracelet as shown.

d. Turn the drill and you will see the bracelet rise and revolve in a horizontal plane.

e. Support a *short, light* necklace or chain, as shown.

f. Turn the handle and you will see the necklace rise and revolve in a horizontal plane.



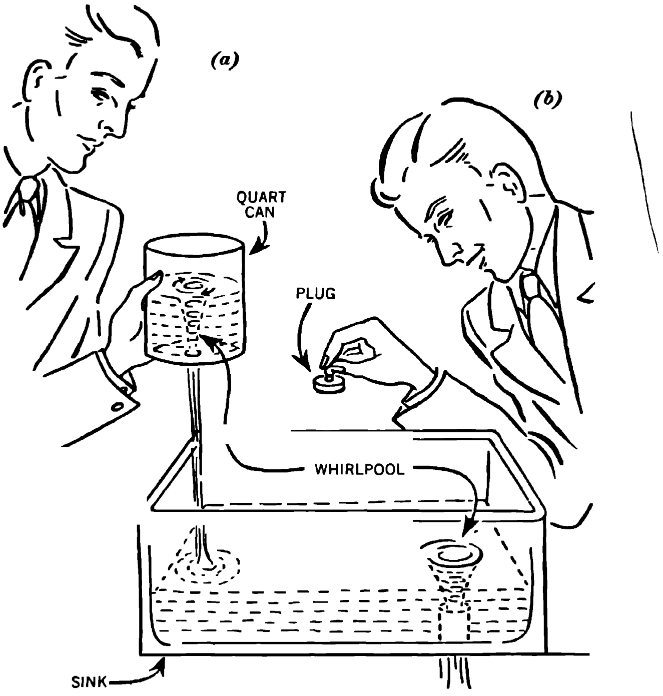
80. Centrifugal Force with Water

a. Support a squat coffee can, as shown, and pour water into it to a depth of one-half inch.

b. Turn the handle and you will see the water crawl up inside the can and over the top. It will scatter in a circle on the table.

c. Support a small, *squat, spherical* goldfish bowl or flower bowl as shown. Pour water into it to a depth of one inch and add a half-teaspoonful of ink to color it.

d. Turn the handle and you will see the water leave the bottom of the bowl. It will form a circular band at the middle.

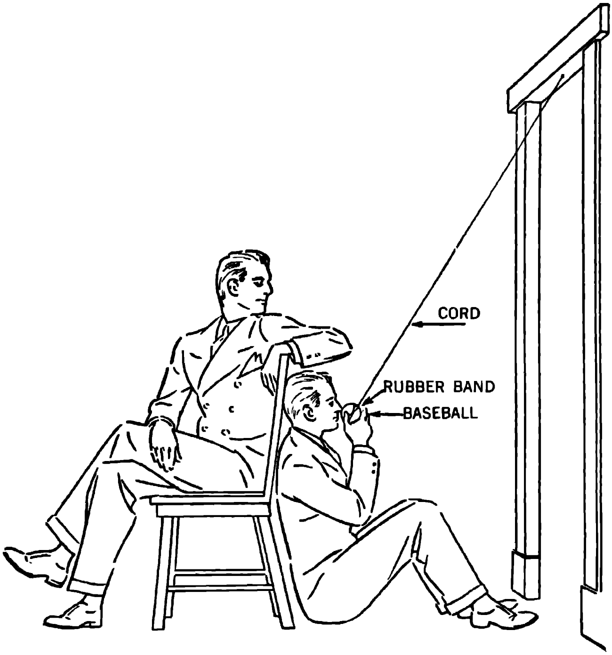


81. You Make Whirlpools

a. Use a large scissors with closed blades to punch a half-inch hole in the bottom of a large empty food can. Twist the blades around to make the hole circular. Hold a finger over the hole and fill the can with water. Then use another finger to start the water revolving.

Open the hole. You will see a small whirlpool in the can.

b. Fill a sink or washbowl with water and start the water revolving. Then pull out the plug and you will see a larger whirlpool.



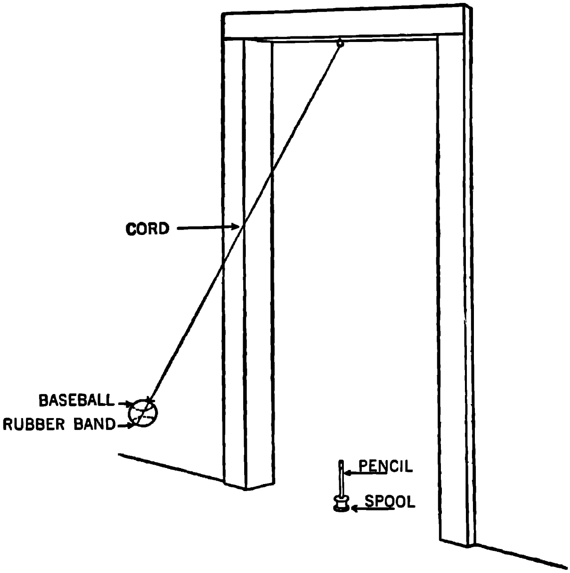
82. Nose Pendulum

Make up a baseball pendulum. Sit on the floor with the back of your head against the back of a chair on which someone is sitting.

Hold the baseball against your nose and release it.

You will think it is going to hit your nose on the return swing, but it will not, unless you give it a push at the start.

Why? See page 243.



83. Pendulum Game

Tie one end of a cord to a rubber band and stretch the band around a baseball.

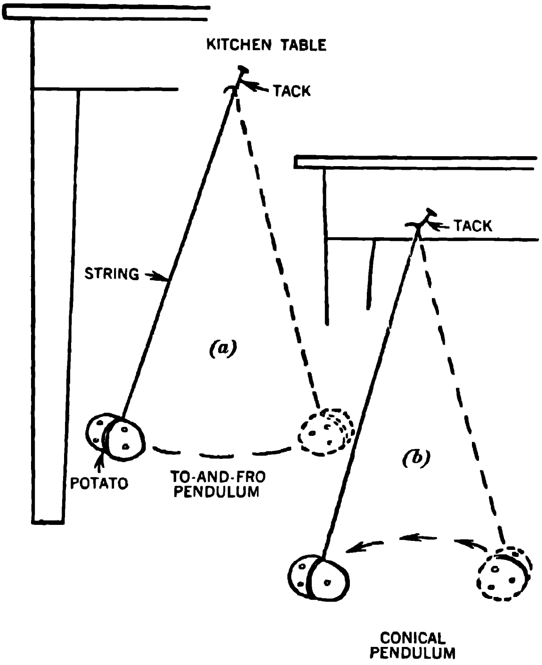
Suspend this pendulum in a doorway and make its length such that the ball hits the top half of a pencil which stands in the hole of a spool on the door sill.

Place the pencil and spool in such position that the top of the pencil is hit when the ball is at the lowest part of a straight forward swing.

Now draw the ball back about 4 feet and try to swing it in such a way that it *misses* the pencil on the *forward swing* and *strikes* it on the *back swing.*

It is difficult to do.

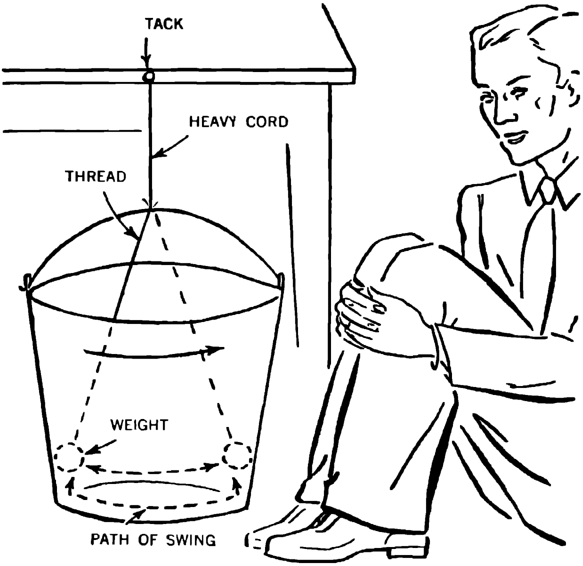
Use only *one* to-and-fro swing at each trial.



84. The Times Are the Same

a. Make a pendulum with a cord and a heavy raw potato, as shown. Then use the second hand of a watch to find the time it takes the pendulum to make ten complete over-and-back swings.

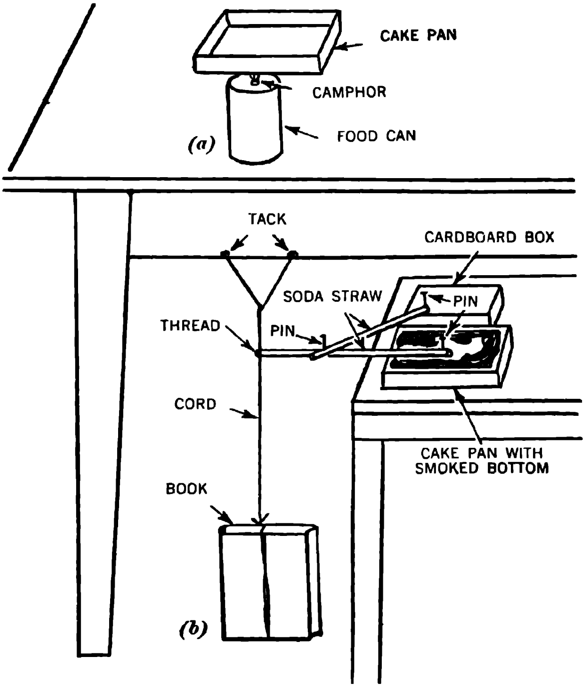
b. Find the time it takes the same pendulum to make ten complete circular motions and you will find the times to be equal.



85. A Pendulum at the North Pole

Suppose you were at the north geographic pole and had a pendulum which would keep on swinging for twenty-four hours. The "path of swing" of the pendulum would remain constant in the same plane, but to you it would appear to turn through 360°, because the earth revolves through 360° in twenty-four hours.

To illustrate: Hang a large pail (the earth) on a stout cord (the earth's axis) and hang a weight on a thread just below the cord (a pendulum at the North Pole). Turn the pail through ten complete turns to twist the cord, start the pendulum swinging, and release the pail. You will see "the path of swing" remain constant in the same plane while the pail (the earth) revolves around it.



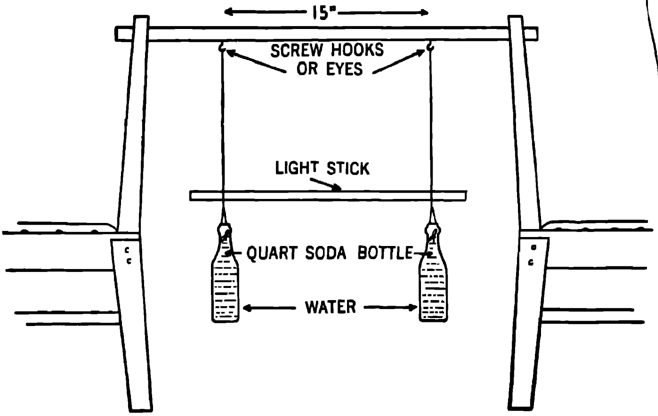
86. It Draws·Beautiful Designs

a. Light a piece of gum camphor, about $\frac{1}{4}''$ x $\frac{1}{4}''$, on the solid end of an empty food can, and smoke thoroughly the bottom of a metal or glass cake pan.

b. Arrange a pendulum, as shown. A thread passed through the left end of the near straw, and tied to the cord, permits the straw to turn sidewise. The right end is pierced by a pin which rests on the smoked surface. The near end of the other straw turns freely on a pin stuck through it and through the near straw. The far end turns freely on a pin stuck through it and into a cardboard box.

Swing the pendulum and it will make the pin on the smoked surface trace out beautiful designs.

Note. **Kerosene will help you clean the bottom of the cake pan.**



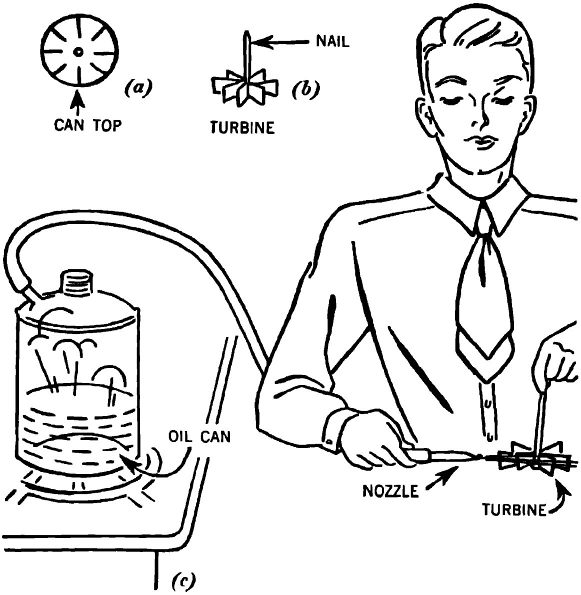
87. Alternating Pendulums

Arrange the equipment, with two pendulums of exactly the same length.

Hold one bottle and start the other swinging as a pendulum, then release the first bottle.

The swinging pendulum will gradually stop and the second pendulum will gradually start swinging.

Then the second pendulum will slowly stop and the first will start swinging again, and so on.



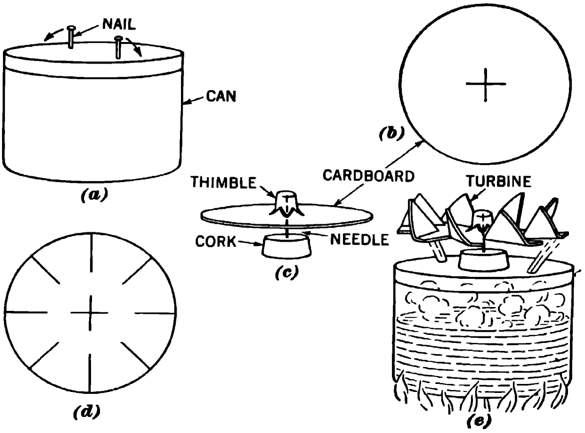
88. You Make a Steam Turbine

a. Find the cut-out round top of a food can, and punch a nail hole at its exact middle. Then make, around its rim, eight equally spaced cuts to within ½ inch of the hole.

b. With a pair of pliers turn the rim sections at right angles to make blades. Use a thinner nail, head down, for the axle of the turbine.

c. Pour a quart of water into an empty oil can, screw on the top, and fasten one end of the rubber tube of a fountain syringe air-tight over the spout. Get up steam and direct it against the blades as shown. You will see the steam jet turn the turbine very rapidly.

Warning. **To avoid steam burns, turn the spout of the can away from you, as shown, and do not boil the water too vigorously.**



89. You Make Another Steam Turbine

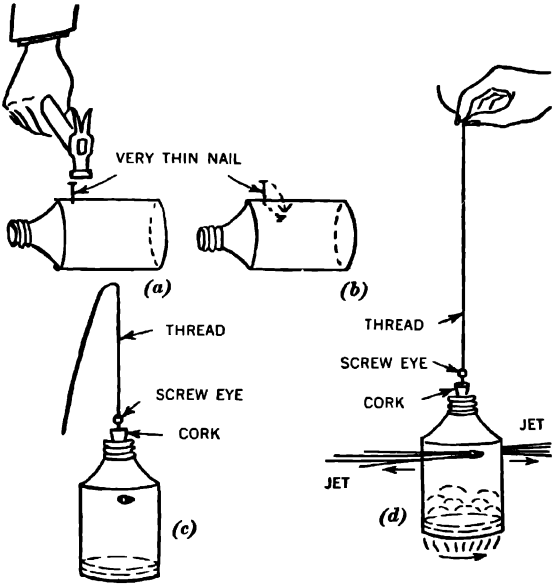
a. Punch two thin nail holes in the cover of a coffee can, on opposite sides and ½ inch from the edge. Then use the nail to bend the holes in opposite directions, as shown.

b. Draw on cardboard a circle the size of the coffee can and cut it out. Then cut at right angles, at the center, two slits 1 inch long.

c. Force a thimble upward into the slits and support the thimble and cardboard on a needle in a cork slice, as shown.

d. Cut eight equally spaced 1¼-inch slits in the rim of the cardboard.

e. Bend the segments to make paddles, mount the turbine, and boil water in the can. You will see the two steam jets revolve the turbine very rapidly.



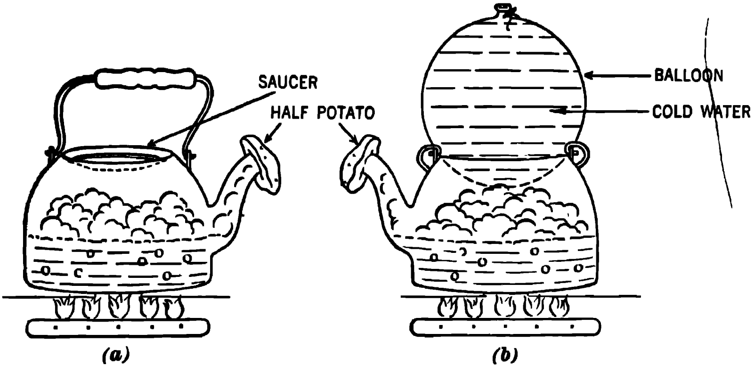
90. You Make a Steam-Jet Reaction Turbine

a. Find an empty tin can similar to those in which benzine is sold. Then use a needle or a very thin nail to punch two thin opposite holes in the side near the top.

b. Use the needle or thin nail to bend the holes in opposite directions.

c. Twist a screw-eye into the middle of the cork top and tie to the eye a long thread for a handle. Pour boiling water into the can to a depth of about one-half inch.

d. Hold the can over a fire, as shown, and soon two opposite steam jets will revolve the turbine rapidly.



91. Steam Engine Power Strokes

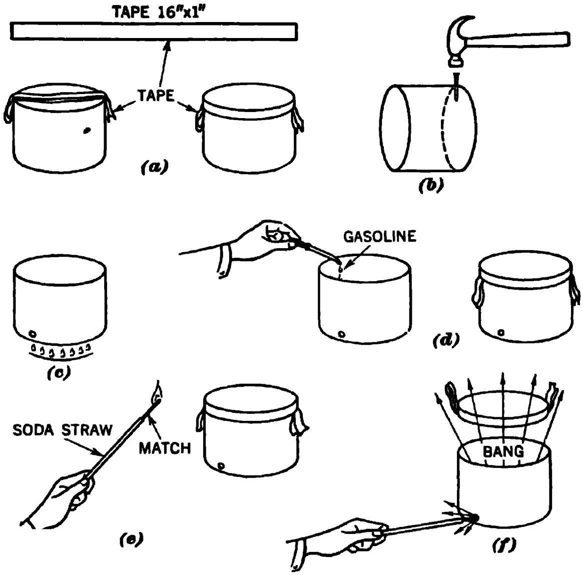
a. Shove half of a raw potato over the spout of a tea-kettle and use a saucer instead of the cover.

Get up steam and turn the saucer slowly.

You will find a position where the saucer rattles enthusiastically. Each rattle is a power stroke.

b. Fill a round five-cent balloon with cold water until it is about 1½ inches larger in diameter than the top opening of the kettle. Tie the balloon and use it instead of the saucer.

The balloon will puff and dance merrily. Each puff is a power stroke.



92. Gasoline Engine Power Stroke

a. You need a *tight* cover to get a nice loud BANG in this experience and in the next two. Make the cover of an empty vacuum-packed coffee can *tight* in this way: Cut a 16-inch length of tape 1 inch wide. Fold it, wet it to prevent it from burning, and use it under the cover, as shown.

b. Punch a hole in the side of the can near the bottom and make the hole just large enough to admit a burning match without extinguishing it.

c. Heat the bottom of the can about five seconds to help vaporize the gasoline.

d. Move the can away from the fire. Put in four drops of gasoline. Put the cover on *tight*. Then wait a half minute to let the gasoline vapor mix with the air in the can.

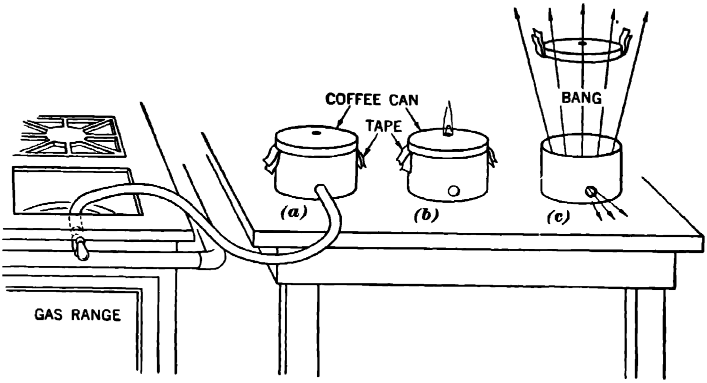
e. Put the butt end of a kitchen match into one end of a soda straw, or tie the match to one end of a stick. Light the match.

f. Put the lighted match into the hole and you will see and hear a fine power stroke.

Warning 1. Use only a small bottle of gasoline. Keep it sealed and keep it a long distance from any fire.

Warning 2. The flame shoots out of the small hole, and so be sure to use a soda straw or stick as a long handle to the match.

Note. If you use too much gasoline, its vapor will drive so much air out of the can that there will be no power stroke.



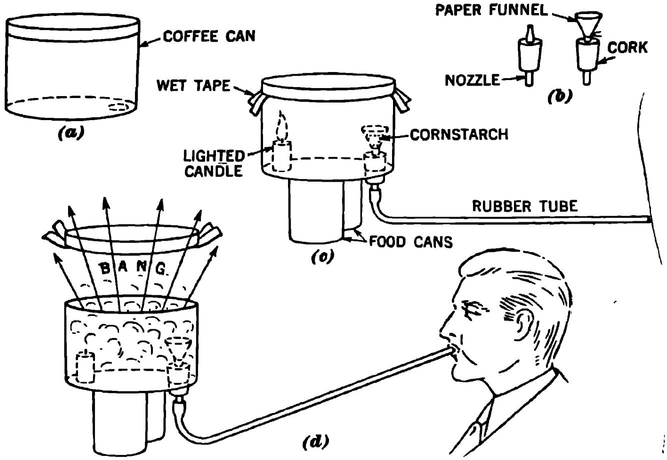
93. Gas Engine Power Stroke

a. Use the coffee can and tape of the last experience, but make the hole in the side of the can large enough to admit the end of the rubber tube from a bath spray or fountain syringe. Make a similar hole in the cover of the can near its edge.

Remove one burner of a gas range, shove one end of the rubber tube of a bath spray or fountain syringe over the spud, and put the other end of the tube in the hole in the side of the can. Put the cover on *tight* with the aid of the wet folded tape. Turn the gas on full for five seconds.

b. Shut off the gas. *Pull the rubber tube out of the can.* Light the gas at the top of the can and wait for the power stroke.

c. The power stroke will come when the flame ducks under the cover. It makes a fine loud BANG, but it is perfectly safe.



94. Powdered-Fuel Engine Power Stroke

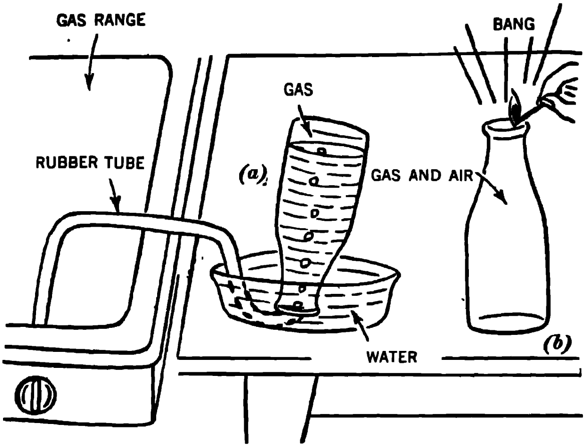
a. Find another empty one-pound vacuum-packed coffee can. Make a round hole about ¾-inch in diameter in the bottom of the can near one side.

b. Find a cork to fit the hole and make a hole through the cork large enough to hold, air-tight, the nozzle of a fountain syringe. Pass the nozzle up through the cork, as shown, and tie a small paper funnel to it.

c. Shove the cork into the hole. Connect the rubber tube to the nozzle and stand the can on two food cans, as shown. Use *cornstarch* to represent the powdered fuel, putting a *level* teaspoonful of it in the paper funnel. Cut a one-inch length of candle. Light the candle and stand it in the can on the side opposite the funnel. Now let one experimenter use the wet tape to put the cover on *tight*.

d. Just as soon as the first experimenter has removed his hands let another experimenter blow hard into the rubber tube to spread the cornstarch.

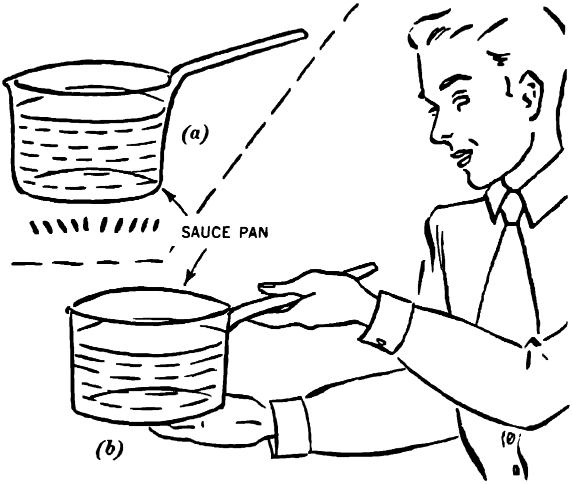
You will see and hear a fine loud power stroke.



95. Whoosh Bang

a. Use a gas burner and rubber tube as described in Experience 93. Fill a quart milk bottle with water, hold a hand over its mouth, invert it in a pan of water, and remove your hand under water. Pass *only one inch* of gas into the bottle. Then lift the bottle upside-down to let it fill with air as the water flows out.

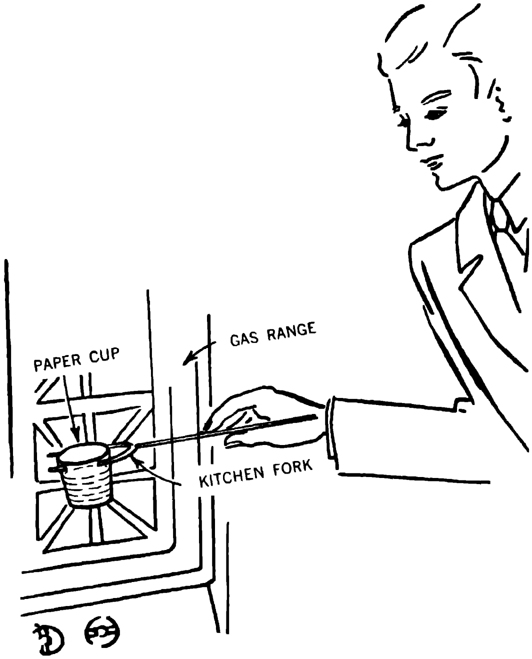
b. Close the bottle with your hand and stand it right-side-up on the table. Light a match, remove your hand, and drop the flaming match into the mouth of the bottle. You will hear a loud "Whoosh Bang." The explosion is noisy but perfectly safe.



96. You Get Water from Fire

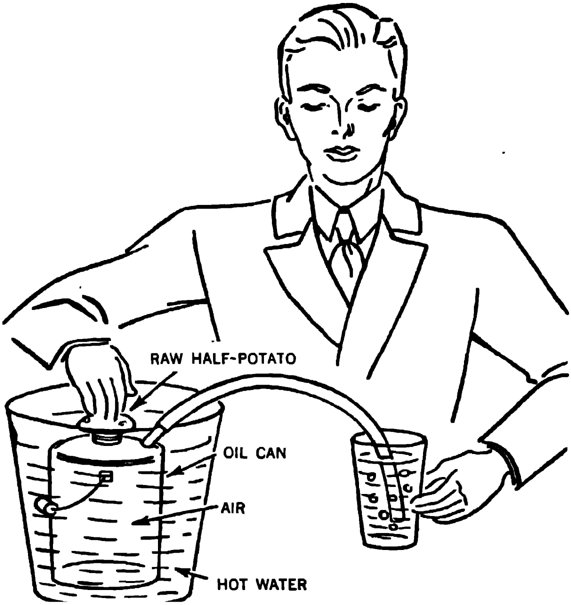
a. Light a gas or oil burner and turn it very low. Then feel the under side of a sauce-pan to be sure it is dry, fill the sauce-pan half full of cold water, and place it over the burner for about fifteen seconds.

b. Lift the sauce-pan off the burner. Feel its under side again and you will find that it is wet.



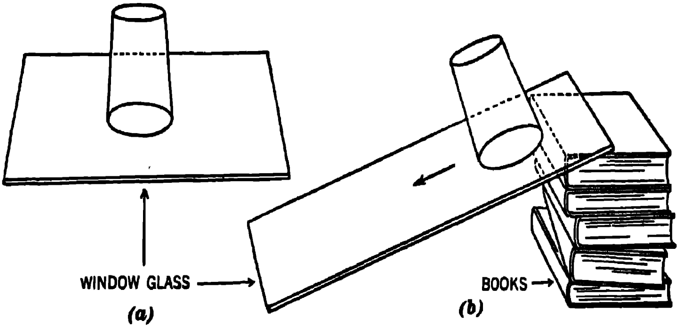
97. You Boil Water in a Paper Cup

Shove the tines of a long-handled kitchen fork through the sides of a paper cup just under its top rim. Fill the cup with water to a point near the top. Hold the cup over a lighted burner, turned low, and you will boil the water without burning the paper.



98. Heat Expands Air

Shove one end of the rubber tube from a bath spray or fountain syringe over the spout of an air-filled oil can and tie the connection, if necessary, to make it air-tight. Place the other end of the tube in a glass of water. The screw cap of an oil can is usually not air-tight, and so in place of it use the flat side of half of a raw potato held down air-tight. Now shove the air-filled oil can down into a pail of hot water and you will see many, many air bubbles in the tumbler.



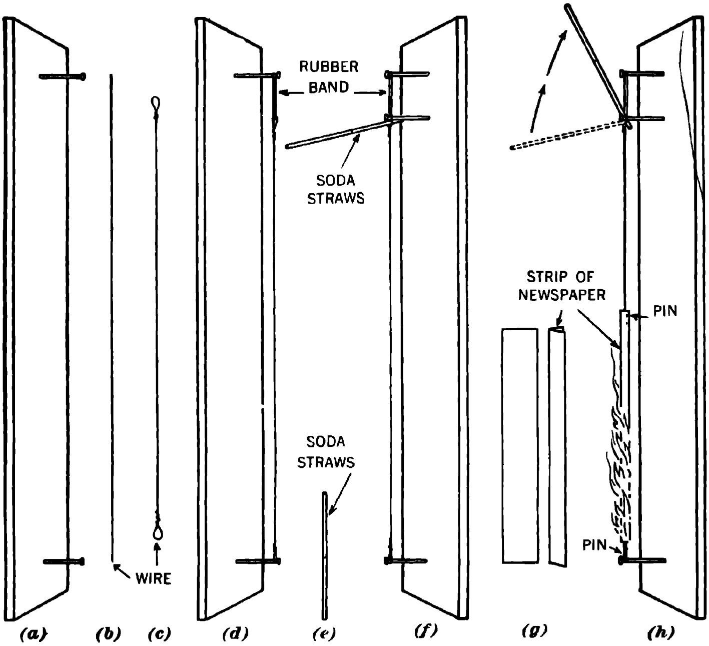
99. A Skiing Tumbler

a. Secure a piece of window glass and invert one tumbler after another on it until you find one with a rim that touches the glass at every point.

b. Now tilt the window glass until you reach the angle at which the inverted tumbler is just about to slide but does not do so.

Fill the tumbler with *hot* water, empty it and place it upside down near the high end of the glass.

Presently the tumbler will ski gracefully down the hill.



100. The Wire Expands

a. Find a board about 7 feet long, 6 inches wide, and 1 inch thick and drive two 4-inch spikes into it exactly 6 feet apart.

b. Cut a wire exactly 6 feet long.

c. Twist exactly 3 inches at each end into a loop.

d. Put one loop over the lower spike *near its head*, and attach the other loop to the upper spike *near its head* by means of 4 stretched rubber bands.

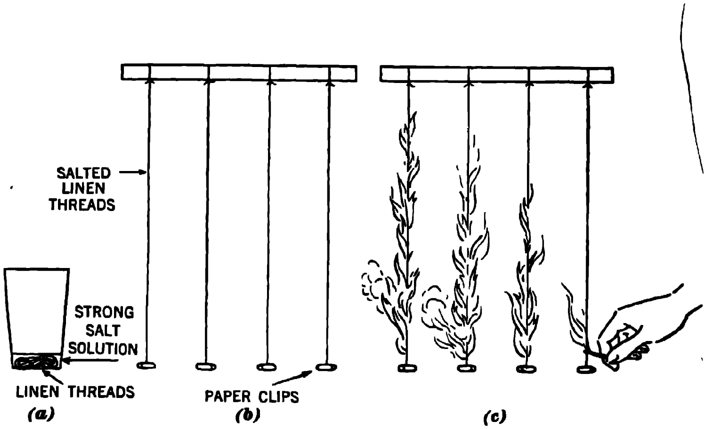
e. Slit one end of a soda straw for 1 inch and slide this end into the end of another soda straw, to make a light pointer.

f. Drive in a third 4-inch spike in such position that it touches the upper loop and its *under* side is at the *middle* of the loop. Insert the soda-straw pointer into the loop with the inserted end *under* the spike.

g. Cut a 3-inch strip of newspaper about 3 feet long and fold it lengthwise.

h. Pin the paper around the *lower* end of the wire and light it at its lower end.

You will see the outer end of the pointer rise when the wire is heated and sink when it cools.



101. To Support a Weight on a Burned Thread

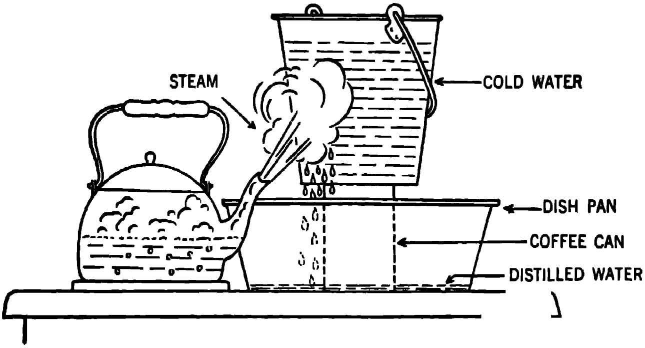
a. Put a heaping tablespoonful of table salt into a tumbler and wet it with two tablespoonfuls of water.

Cut 4 *heavy* linen threads 18 inches long and soak them in the salt water for five minutes or more.

b. Tie each thread to a support and attach a paper clip, or other light weight, at its lower end. Let the threads dry over night.

c. Light each thread with a match and the burned thread will support the light weight.

Note. **The thread must be linen.**



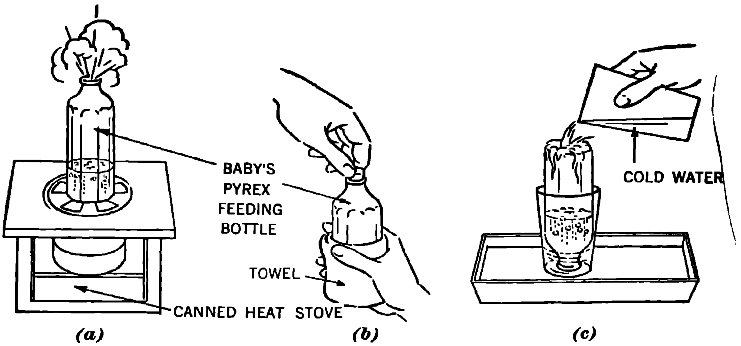
102. To Get Distilled Water for Your Battery

Clean the outside of a pail and a coffee can, then clean the inside of a dish-pan.

Put a kettle of water over the fire and let the steam strike the outside of the pail of cold water which stands on the coffee can in the dish-pan.

The distilled water, condensed steam, will drop into the dish-pan.

Note. **Renew the cold water about every half hour.**



(a) (b) (c)

103. To Boil Water by Cooling It

a. Buy a baby's Pyrex feeding bottle with a sound cork stopper. Pour hot water into it to a depth of about 1 inch. Boil the water until the steam has issued for one minute or more.

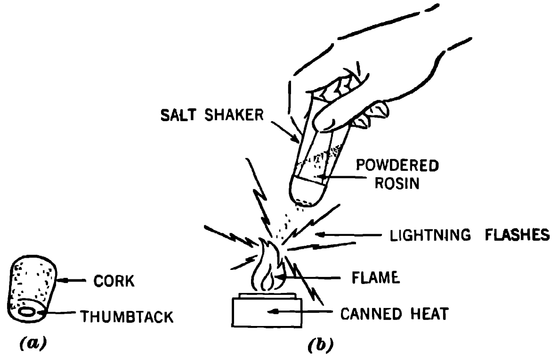
b. Then take these steps in order:

1. Put out the fire.
2. Put a towel around the bottle, hold it standing on the table, and insert the cork firmly.

c. 3. To make sure that the stopper will not let in air, invert the bottle into a small tumbler of water and stand them in a baking pan or other flat vessel.

4. Pour cold water a little at a time over the bottle, and the water in the bottle will boil a long time, although it is getting cooler and cooler.
5. To pull out the cork easily, heat the bottle right side up in a sauce-pan of boiling water for about five minutes, lift it out and remove the stopper.

Note. **Baby's Pyrex bottles cost 25 cents at a drug store. Sterno stoves cost 35 cents, Sterno Corporation, 9 East 37th Street, New York City. Sterno cans cost 10 cents each.**



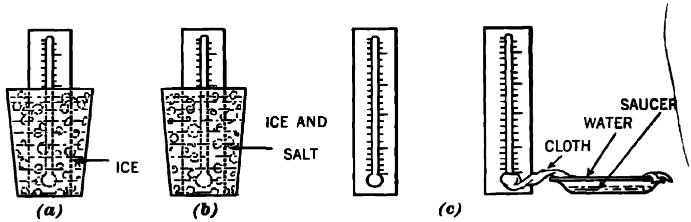
104. Heat and Lightning

a. *Heat*. Stick a thumbtack with rounded head into one end of a cork and rub it vigorously back and forth on the carpet or floor, then touch it to the back of your hand.

You will find it hot.

b. *Lightning*. Powder rosin very fine, place it in a salt shaker, and shake it into a flame, preferably in the dark.

You will see bright flashes resembling lightning.



105. Thermometer Experiences

a. *To test your thermometer.* Put it into a tumbler of cracked ice and a little water.

It will register 32° F. if it is accurate.

b. *To find the temperature of ice and salt.* Place the thermometer in a tumbler containing salt and *very finely powdered ice*, mixed in the proportion of 1 salt to 3 ice, by weight.

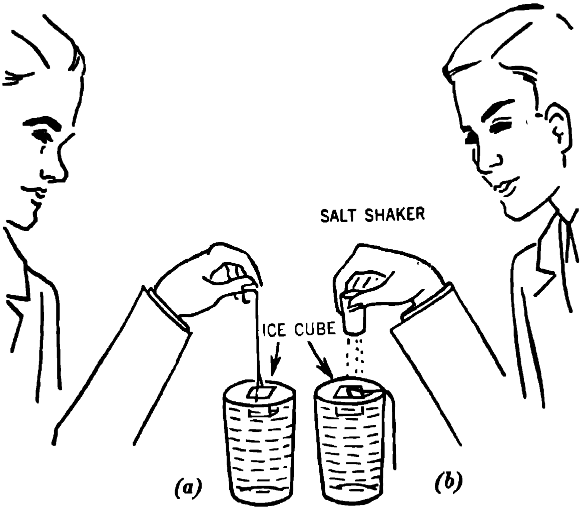
The lowest possible temperature for the mixture is minus 7.6° F.

c. *Air humidity.* Tie one end of a piece of old handkerchief to the bulb of a thermometer and let the other end dip into a saucer of water.

After the handkerchief and bulb are wet, stand a dry-bulb thermometer near by and fan both vigorously.

The less the difference in temperature the greater the humidity, and vice versa.

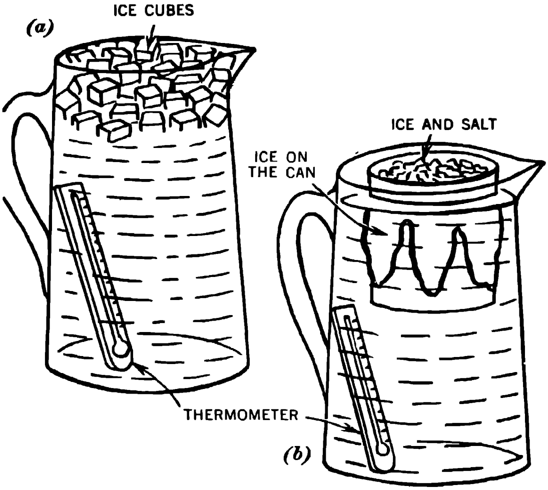
Note. **You can buy ten-cent thermometers at the five and ten cent stores. Be sure the liquid thread in the stem is not broken.**



106. A Trick

a. Float an ice cube in a tumbler of water and ask your friends to try to lift it out with a loop of string.

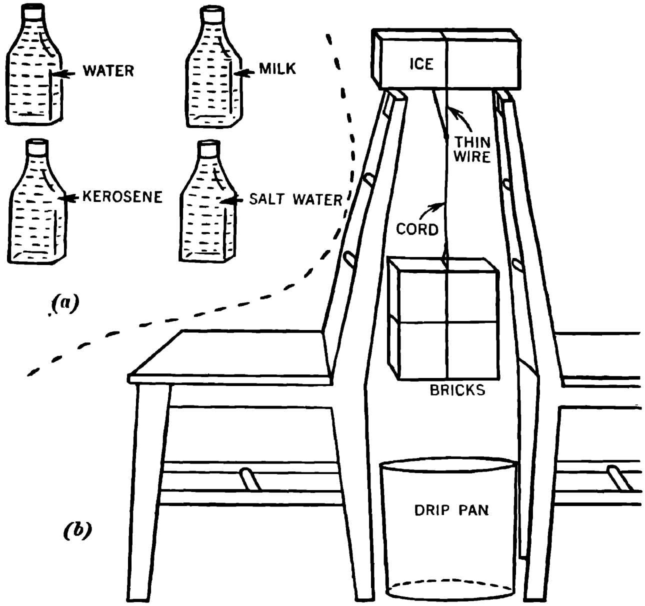
b. When they fail, lay the *wet* loop on the ice cube and sprinkle it with salt. After two or more minutes, lift the string and you will lift out the ice cube.



107. The Heaviest Water Is at 39.2° F.

a. Fill a tall transparent glass pitcher nearly full of cold water. Weight a thermometer so that it will sink and put it in the water. Float ice cubes in the water and observe the thermometer after one hour or more. You will find that the temperature of the water at the bottom of the pitcher (the heaviest water) is at 39.2° F.

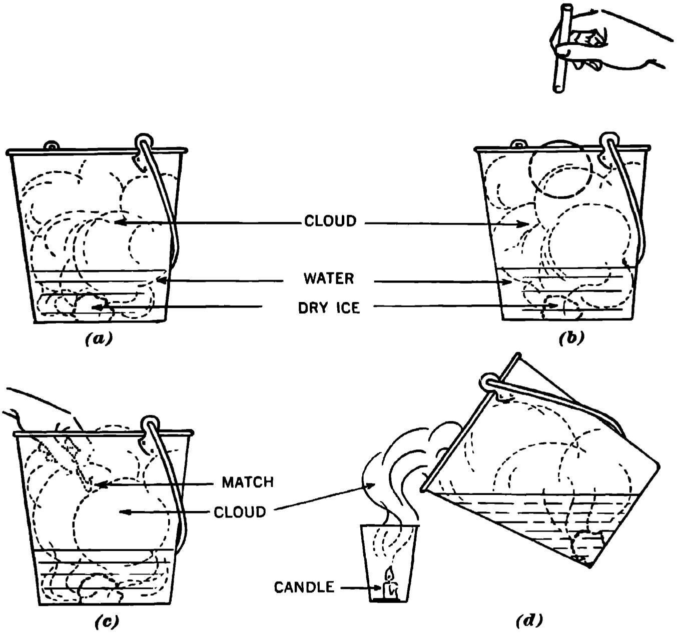
b. Remove the ice cubes. Float in the water a tin can filled with a mixture of cracked ice and salt in the proportion, by weight, of 3 parts ice and 1 part salt. Observe the can and thermometer after an hour or more. You will see that there is ice on the can (32° F.) but that the temperature of the water at the bottom of the pitcher is still 39.2° F.



108. Properties of Ice

a. Fill four three-ounce bottles respectively with water, milk, kerosene, and salt water made by dissolving two level tablespoonfuls of salt in 3 ounces of water. Screw the cap down on each bottle when it is full to overflowing. Place the bottles over night in the ice cube trays of a mechanical refrigerator, or outdoors in freezing weather. In the morning you will find the water and milk bottles broken, but the kerosene and salt water bottles intact.

b. Find a block of ice outside in winter or, in summer, freeze one in the large tray of a mechanical refrigerator. Arrange the block of ice, as shown, in a room warmer than 32° F. and you will see the thin wire pass very slowly through the block without cutting it in two.



109. Dry Ice—Cloud

Warning. Dry ice is very cold, −110° F. Handle it with a teaspoon, not with your fingers.

a. Drop a piece of dry ice into water in a pail.
A dense white cloud will form in the pail.

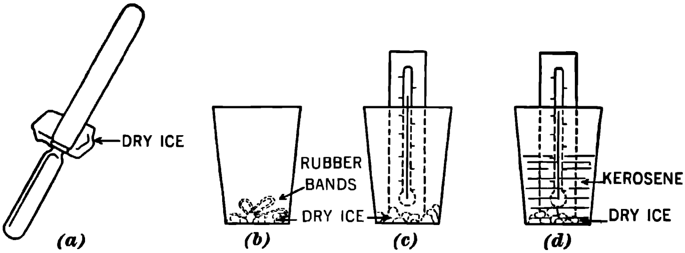
b. Drop a soap bubble into the cloud.
The soap bubble will float in the cloud.

c. Light a match and lower it into the cloud.
The match will go out.

d. Light a short candle in a tumbler and fill the tumbler with cloud.
The cloud will pour like a liquid and extinguish the candle.

e. Repeat Experiences 37 and 39 with the cloud.

Why? See page 246.



110. Dry Ice—Cooling

a. Press the blade of a dinner knife against dry ice and move it slowly lengthwise.

The blade will cry out and groan.

b. Let rubber bands rest on dry ice in a tumbler for five or ten minutes.

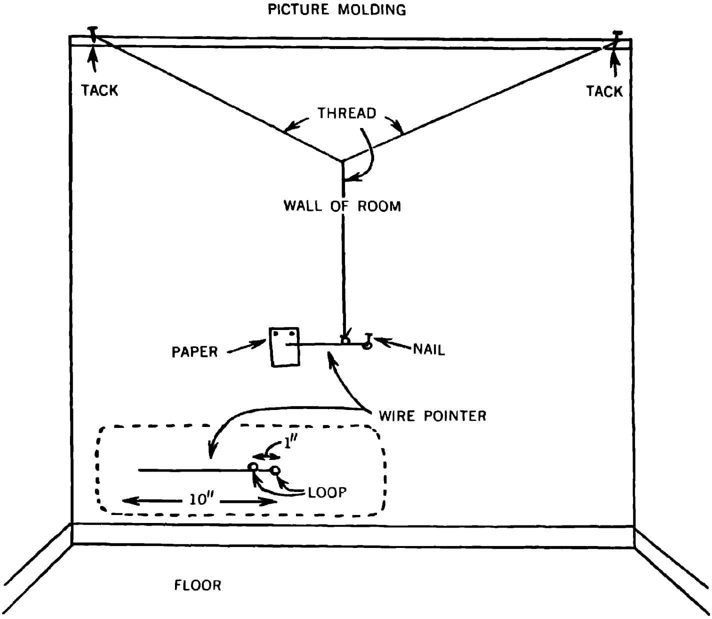
The rubber will lose its elasticity and become brittle.

c. Place a thermometer in a tumbler with dry ice.
It will cool very slowly.

d. Place a thermometer in a half tumbler of kerosene and dry ice.

It will cool more rapidly, but not so rapidly as you would expect.

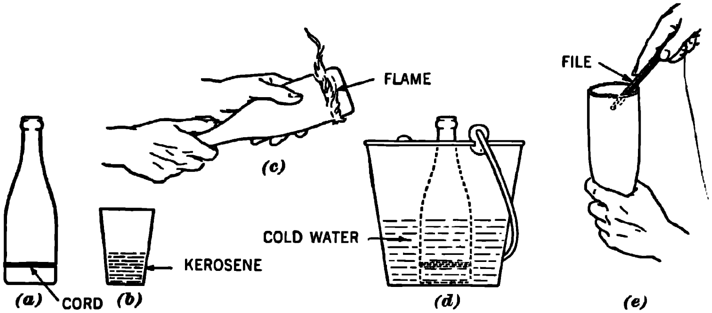
Note. **Buy dry ice at the drug store.**



111. You Make a Humidity Indicator

Drive two tacks, high up and far apart, in a wall which has neither door nor window, and arrange thread, wire pointer, nail, and paper as shown.

If the thread you use is of vegetable origin, as linen or cotton, it will shrink as the humidity increases and raise the free end of the pointer. It will also stretch as the air becomes drier and let the free end of the pointer sink. If, however, the thread is of animal origin, as wool or silk, it will act in the opposite way. That is, it will stretch as the humidity increases and let the free end of the pointer sink. As the humidity decreases, it will shrink and raise the free end.



112. To Cut Off the Bottom of a Bottle

a. Use cotton cord between $\frac{1}{16}$-inch and $\frac{1}{8}$-inch in diameter, not twine. Wrap the cord three times around the bottle, leave enough to tie, and cut it.

b. Soak the cord in kerosene for five minutes.

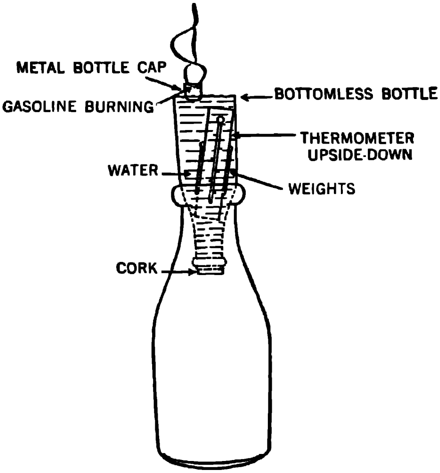
c. Wrap the kerosene soaked cord around the bottle with the loops close together and tie it. Cut off the knot ends.

Hold the bottle nearly horizontal but with the bottom about 2 inches above the top, light the kerosene, and turn the bottle over and over until the flame dies down.

d. Dip the bottom into cold water and hold it there until it is cool. Tap the bottle with a file just below the cord and the bottom will separate.

e. Smooth the sharp edges with a file, outside and inside, just enough to prevent them from cutting you.

The edge will be irregular because most bottles vary in thickness and are imperfectly annealed.



113. To Show that Water is a Poor Conductor of Heat

Use a bottomless quart soda bottle, close it with a cork, and stand it upside down in a quart milk bottle.

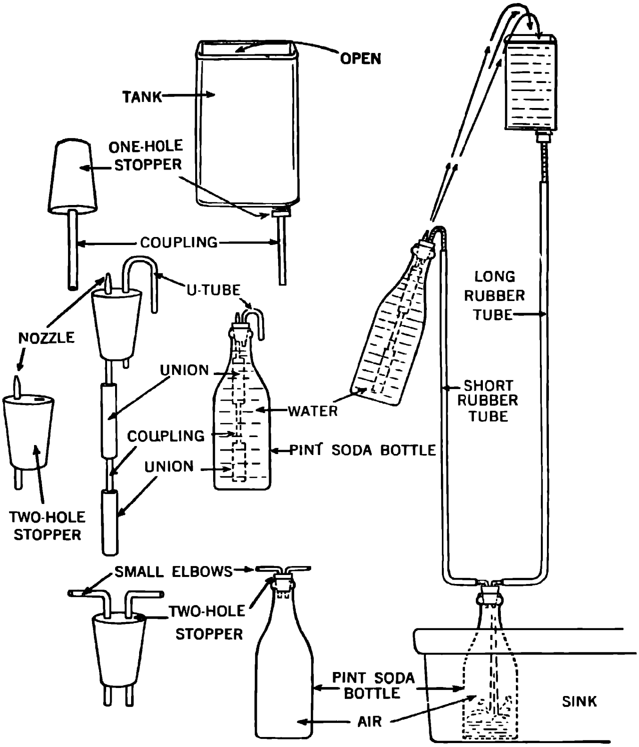
Attach spikes, or other weights, to a short ten-cent thermometer and place it upside down in the bottomless bottle.

Pour cold water into the bottle until the thermometer is covered.

Dig the cork slice out of the metal cap of a vinegar bottle, pour a *half*-teaspoonful of gasoline into the cap, float the cap on the water in the bottle and light the gasoline.

The temperature of the water will change very little if at all.

Water Pressure[1]



114. Is This Perpetual Motion?

Arrange the equipment as indicated, stand the lower bottle in a sink, fill the tank with water, and hold everything as shown.

You will see the stream of water from the nozzle rise above the water surface in the tank.

Note 1. Always wet glass and rubber before you insert glass into rubber.

Note 2. Always separate glass and rubber as soon as you finish an experience, to prevent them from sticking together.

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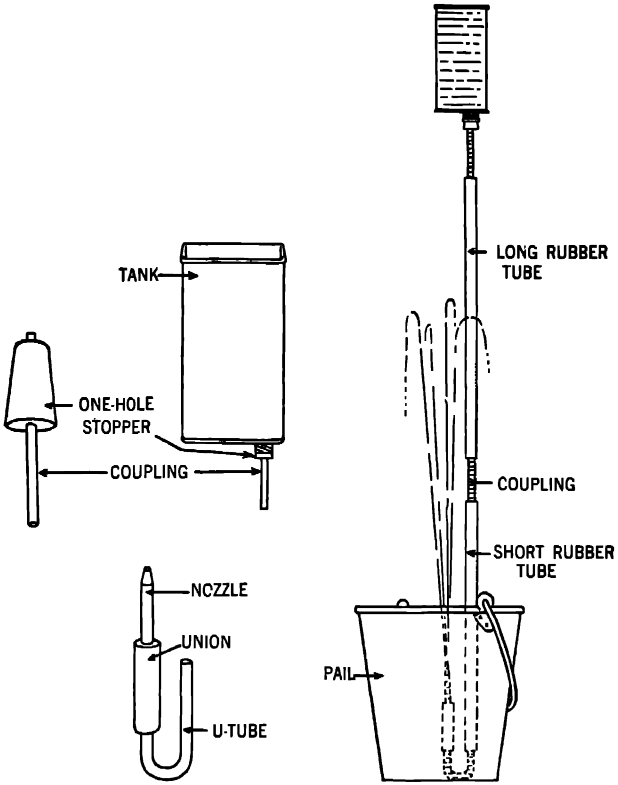
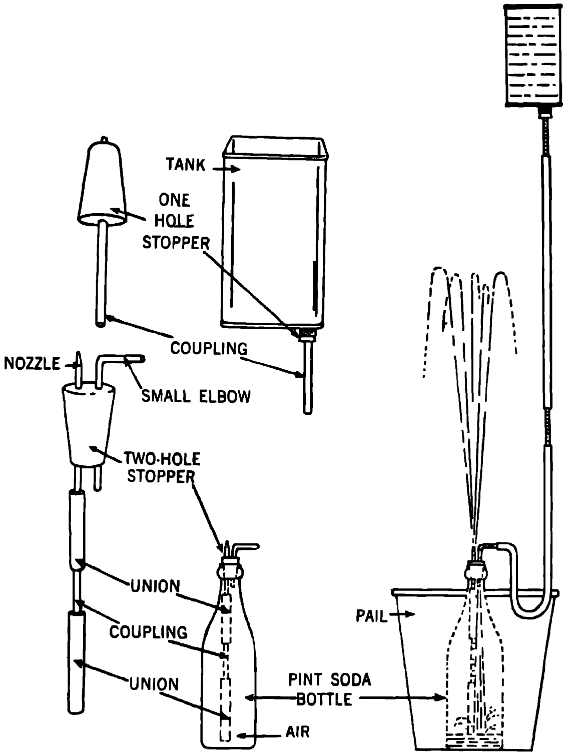
[1] The equipment needed for these experiences is described on pages 214 to 227.



115. A Fountain

Arrange the equipment with the pail on the floor, fill the tank with water, and hold it while standing on a chair.

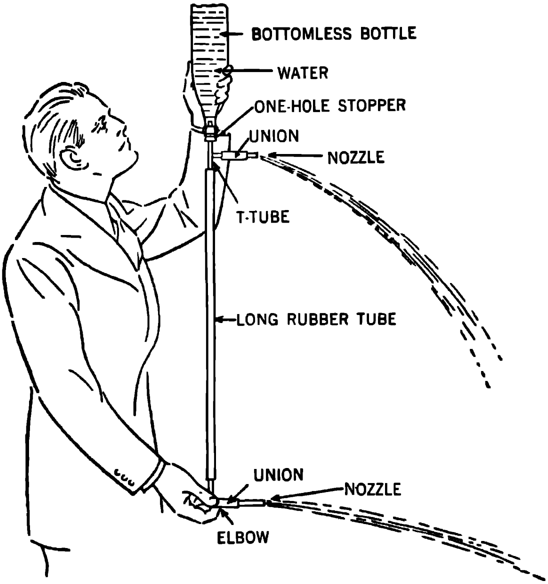
You will see a fine fountain.



116. Another Fountain—

Arrange the equipment with the air-filled bottle in a pail on the floor. Fill the tank with water and hold it up while standing on a chair.

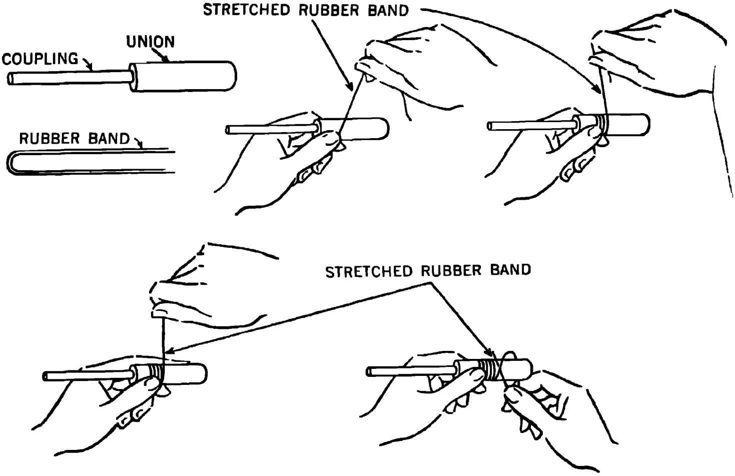
You will see a fine fountain.



117. Unequal Streams

Arrange the equipment, fill the bottomless bottle with water, and hold it as shown. The lower stream will be longer than the upper stream.

Note. Directions for cutting the bottom from a bottle are given on pages 124 and 225.



118. A Secure Fastening

In many of these experiences you will need to fasten securely a glass tube in a rubber tube or rubber balloon. A simple way to do this is by means of a *stretched rubber band*, as follows:

a. Cut one end of the rubber band.

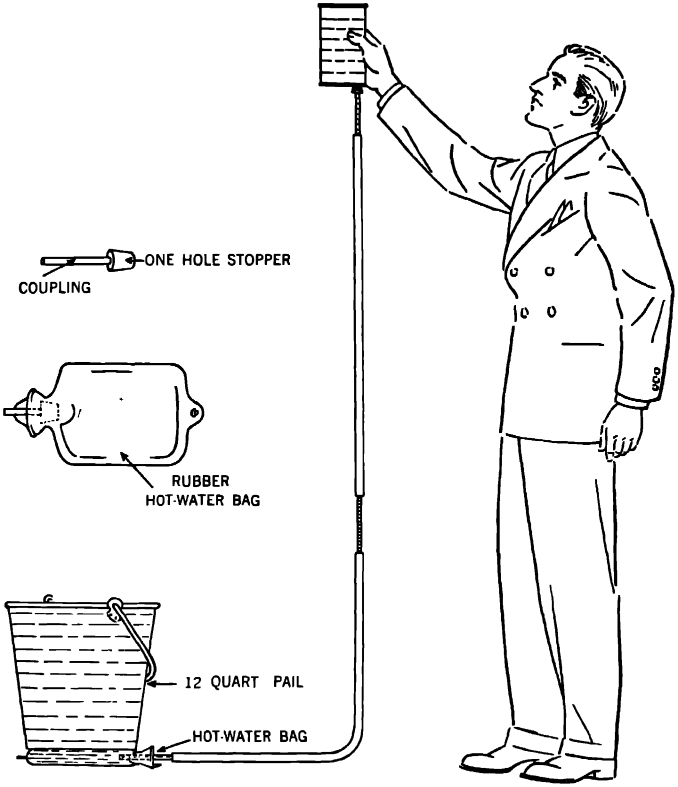
b. Insert the glass tube into the rubber tube.

c. Hold one end of the rubber band against the rubber tube *with the left thumb.*

d. *Stretch the band* and wind it *stretched, each turn on top of the preceding turn.*

e. Extend the left forefinger and wind the last turn over it.

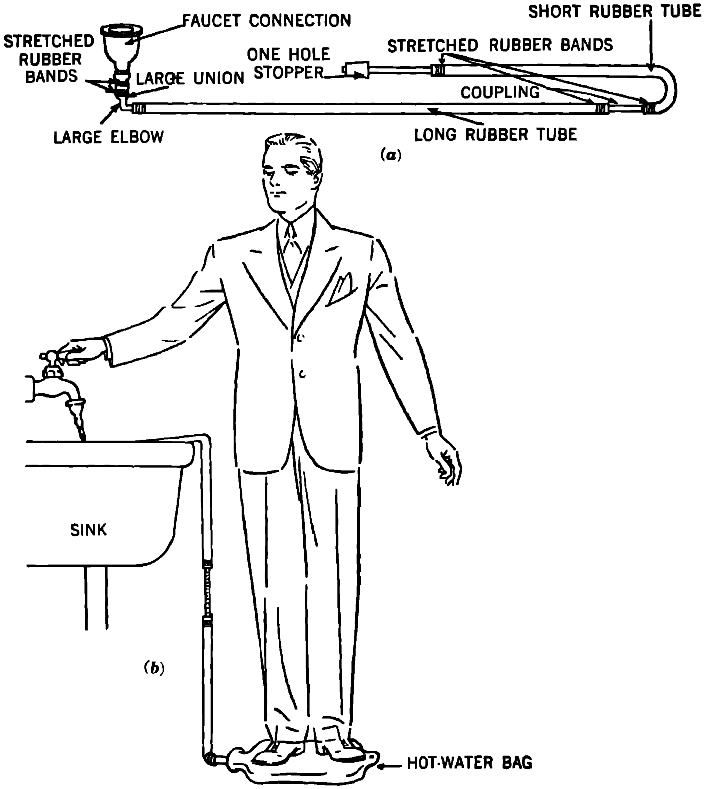
f. Slip the end under this last turn and pull it through. This fastening will hold very securely.



119. A Pint of Water Lifts Twenty Pints

Fill a 12-quart pail nearly full of water and stand it on a rubber hot-water bag arranged as shown. Hold up the tank and keep filling it with water.

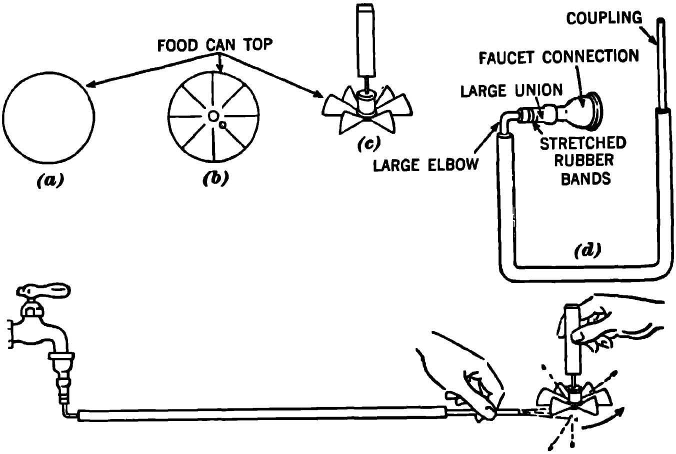
You will see one pint of water in the tank and tubes lift the twenty pints of water and the pail.



120. The Water Lifts You

a. Arrange the equipment.

b. Connect with a hot-water bag and cold-water faucet.
Stand on the bag and turn on the water.
You will feel yourself being lifted.



121. A Water Wheel

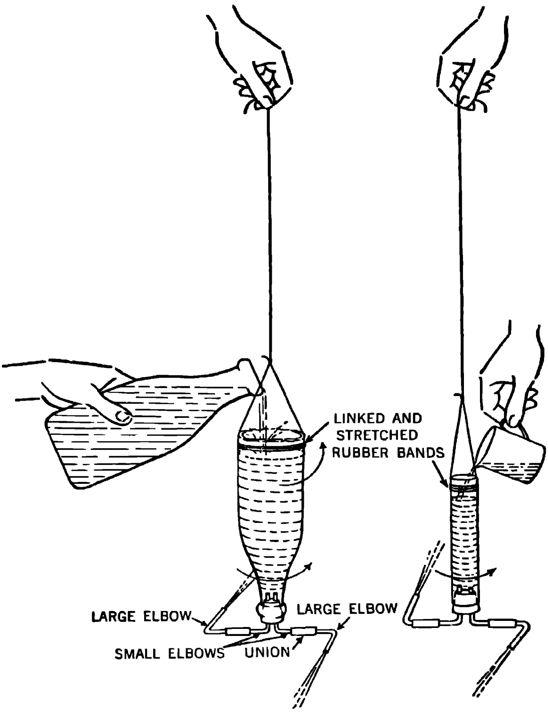
a. Cut out the top of a large round food can.

b. Punch a large nail hole at the center and a smaller hole near it. Divide the top into eight equal segments.

c. Tack the top to one end of a large spool and nail both loosely to a wooden support by means of a nail smaller around than the hole in the top and spool. Bend the segments to make paddles.

d. Arrange the tubing.

e. Connect with a faucet and turn on the water. The water will spin the wheel merrily.



122. Reaction Turbines

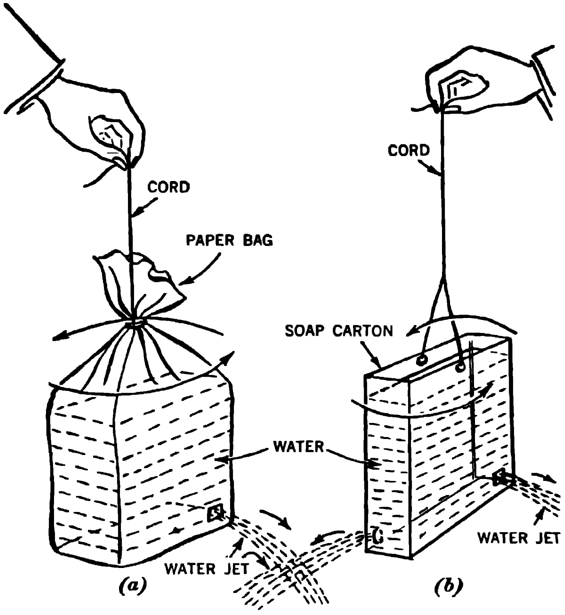
a. Attach a short cord handle to the bottomless bottle by means of three stretched rubber bands linked together. See Experience 129. Attach a long single cord to this handle.

Arrange the stopper, unions, and elbows, and fill the bottle with water.

The reaction turbine will revolve as shown.

b. Repeat with the large glass tube.

The small turbine will revolve more rapidly than the large one.

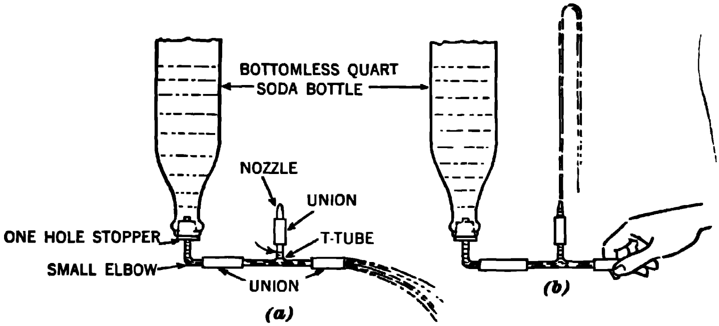


123. Reaction Turbines

a. Fill a paper bag about two-thirds full of water. Tie its mouth with a stout cord and leave one end of the cord for a support. Cut a ½″ x ½″ hole near one lower corner and lift the bag by the long cord. You will see a jet of water shoot out in one direction and turn the bag in the opposite direction.

b. Cut off the top of an empty soap-powder carton. Punch two opposite nail holes in the sides near the top. Tie a short loop to the nail holes and tie to the loop a long single cord for a support. Cut a ½″ x ½″ hole in each of two diagonally opposite lower corners.

Fill the carton with water and lift it by the long single cord. You will see each water jet shoot out in one direction and turn its corner in the opposite direction.

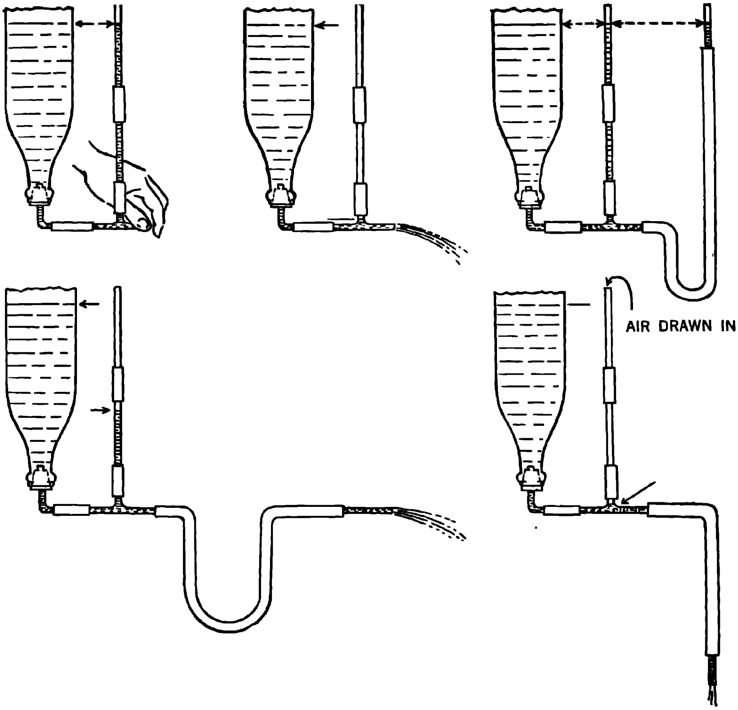


124. Hydraulic Ram

a. Let the water flow from the outlet union and the water level in the side tube will be low. See arrow.

b. Pinch the outlet union to stop the flow suddenly, and the first spurt from the nozzle will shoot up above the water level in the bottomless bottle.

This illustrates the principle of the hydraulic ram.



125. Water at Rest and in Motion

a. The surfaces of the water at rest are at the same level (nearly).

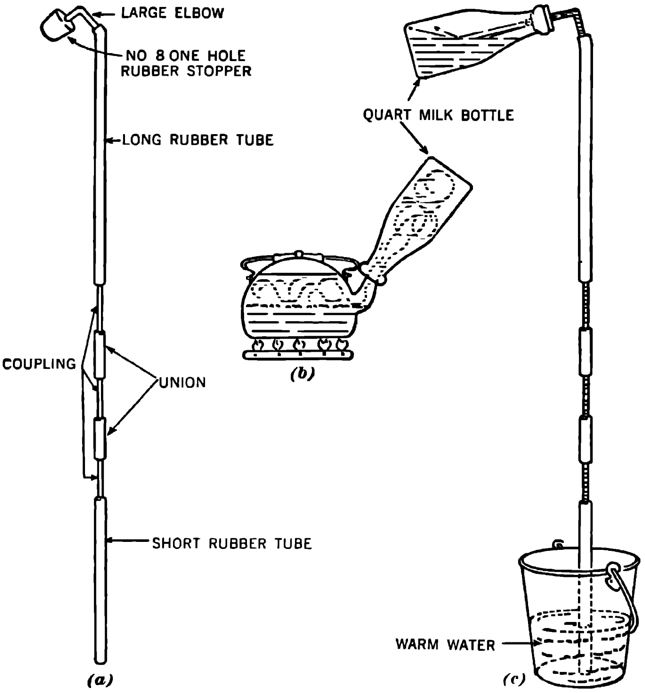
b. The surfaces of the water in motion are not at the same level. See arrows.

c. The surfaces of the water at rest are at the same level (nearly).

d. The surfaces of the water in motion are not at the same level.

e. Water moving rapidly down a vertical tube may draw air in.

Note. Capillarity raises the water level in the small tubes slightly. See Experiences 66, 67, and 68.



126. Water Runs Up Hill Six Feet or More

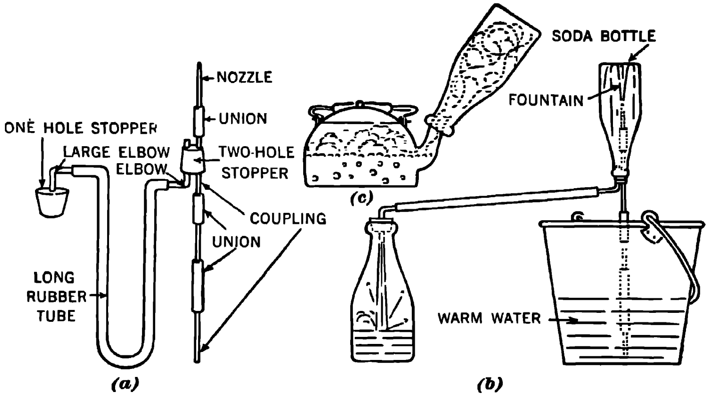
a. Arrange the equipment.

b. Steam the inside of a quart milk bottle for one minute.

c. Fill a pail partly full with *warm water.* Remove the milk bottle from kettle, insert the large stopper into its mouth quickly and raise both, but keep the lower end of the lower tube under water.

Water will run up into the bottle.

Note 1. Warm water will not crack the hot milk bottle.
Note 2. Read *c*, Experience 22.



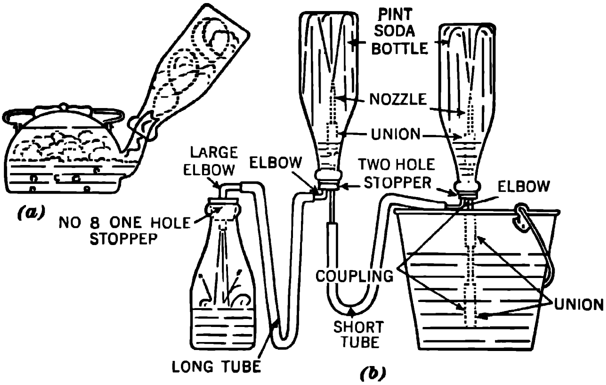
127. A Fountain

a. Arrange the equipment.

b. Steam the inside of a quart milk bottle for one minute and insert the large stopper into it quickly.

c. You will see a fine fountain.

Note. Read *c*, Experience 22.

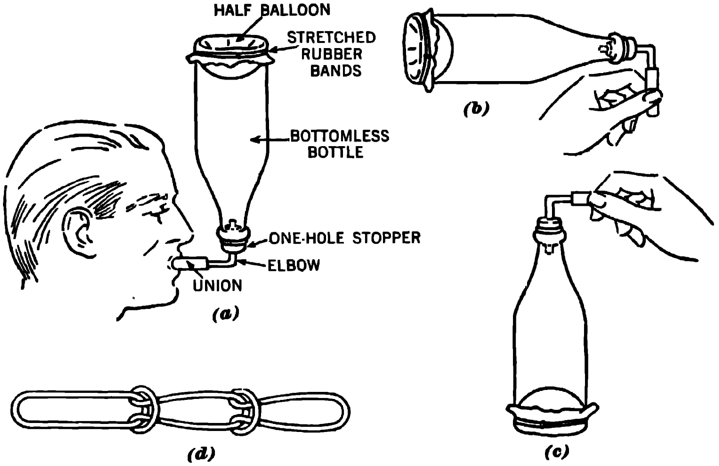


128. A Double Fountain

a. Arrange the equipment as above, steam the inside of the quart milk bottle for one minute, and attach it as shown.

b. You will see a fine fountain in each bottle.

Note. Read *c*, Experience 22.



129. Atmospheric Pressure is Equal in All Directions at a Given Point

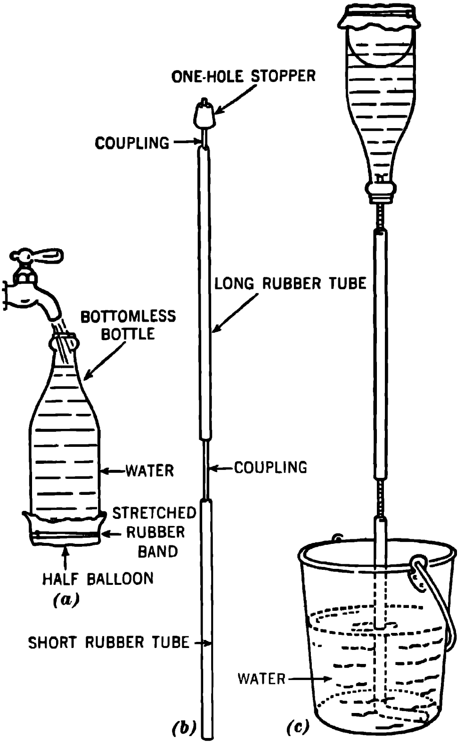
a. Cut a large round five-cent balloon in two and fasten the bottom half over the bottomless end of a quart soda bottle by means of three stretched rubber bands. Insert the stopper with elbow and union.

Suck out air and the balloon rubber will move into the bottle.

b. Pinch the union and turn the balloon end sidewise; the rubber will remain in the same position.

c. Turn the balloon end downward or in any direction and the rubber will remain in the same position.

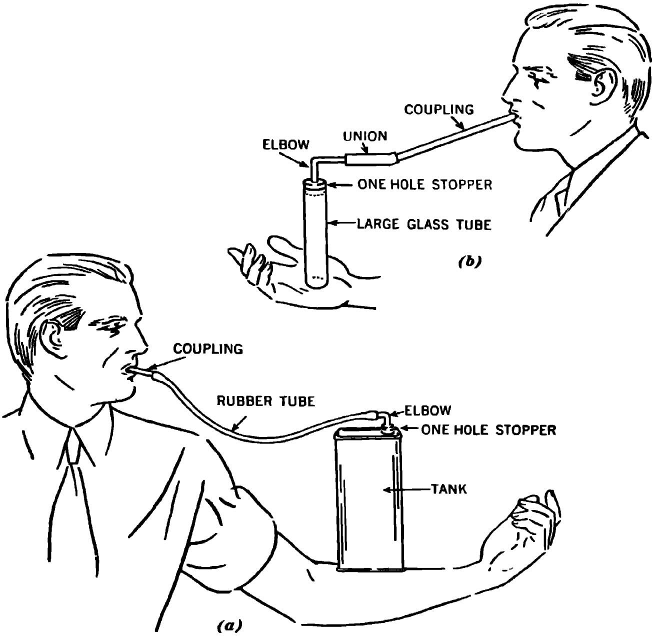
d. For the stretched rubber bands, use three uncut bands and loop the end of one into the end of the next to make a row of three fastened together.



130. Suction

a. b. c. Fill the bottomless bottle of the last experience with water and make the test. Hold the inverted bottle as high as you can and still keep the end of the lower tube in water.

You will see the balloon rubber stretch down into the bottle.



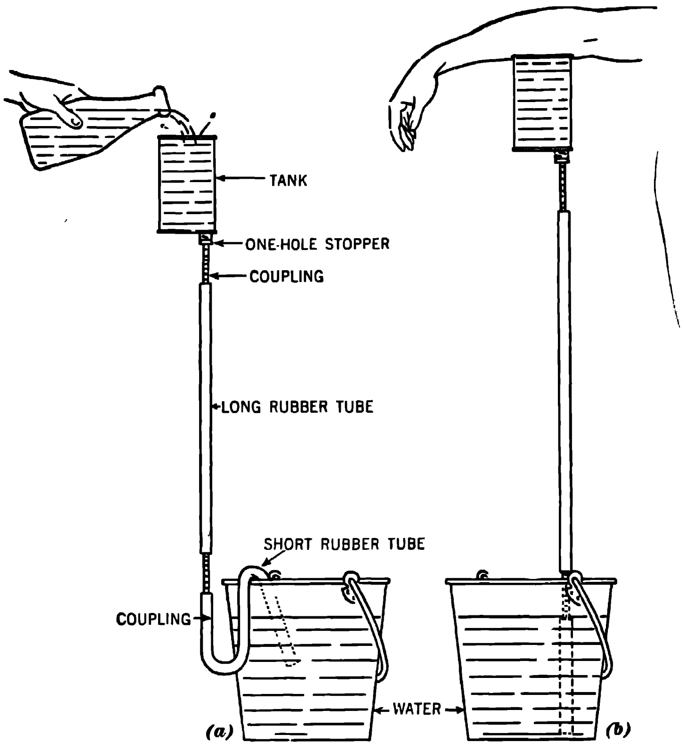
131. To Feel and See Suction

a. To feel suction, roll up your sleeve, press the open end of the tank down air-tight on your forearm, and suck air out of the tank.

You will feel the flesh under the tank move up into the tank.

b. To feel and see suction, press the open end of the large glass tube air-tight against your palm, and suck air out of the tube.

You will feel and see the flesh under the tube move up into the tube.

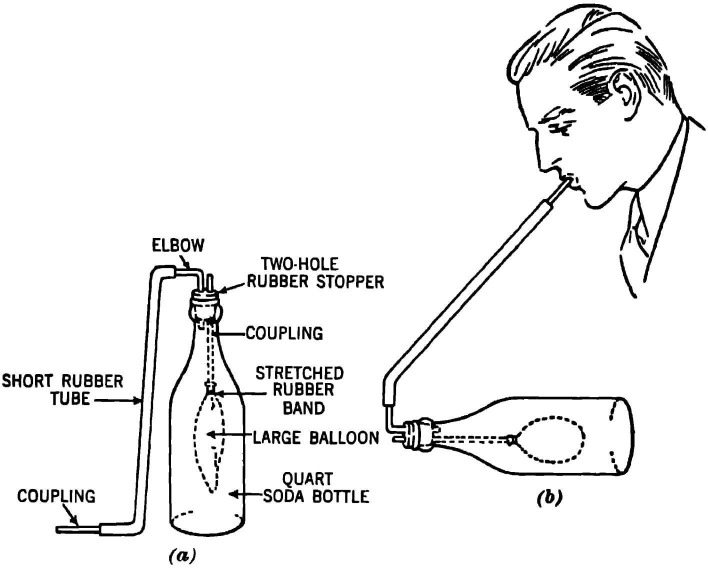


132. To Feel Suction

a. Arrange the equipment.

b. Wet your forearm, press the open end of the tank full of water air-tight against it, stand on a chair, and hold the tank as high as you can and still keep the end of the lower tube under water.

You will feel very strong suction.

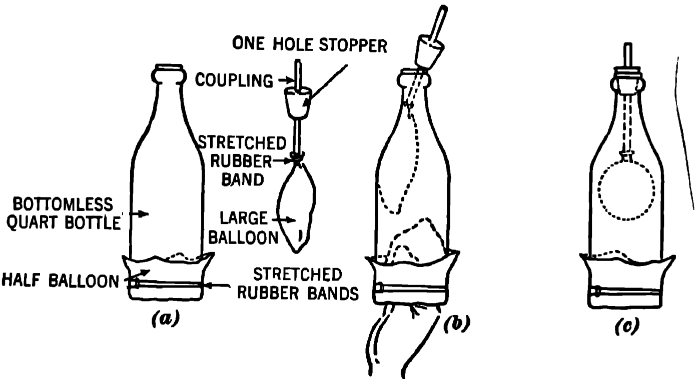


133. A Respirator

a. Arrange the equipment. The large balloon represents the patient's lungs.

b. Suck air out of the bottle and you will see the balloon expand. Let in air and you will see the balloon (lung) contract and expel air.

The Drinker respirator is an air-tight steel box into which the patient is laid with his head outside at one end. An air-tight rubber collar is then fitted about his neck. The pressure of the air in the box is alternately decreased and increased at the intervals of natural breathing and outside air moves into and out of his lungs as in breathing.



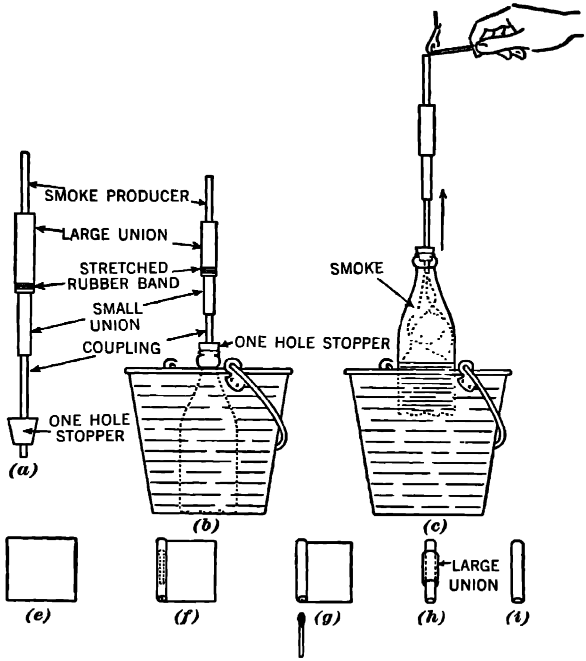
134. Diaphragm and Lung

a. To represent the diaphragm, attach the bottom half of a large round balloon to the bottomless end of a quart soda bottle. See Experience 129.

To represent a lung, attach a large balloon to a coupling in a one-hole stopper.

b. Shove the balloon (lung) into the bottle but do not insert the stopper. Force the diaphragm in by hand to expel air from the bottle.

c. Insert the stopper and remove your hand. The diaphragm will sink and the lung will breathe in. Force the diaphragm in again and the lung will breathe out.



135. The Bottle Smokes

a. Arrange the equipment.

b. Sink the bottomless quart soda bottle in a pail *full* of water and insert the stopper.

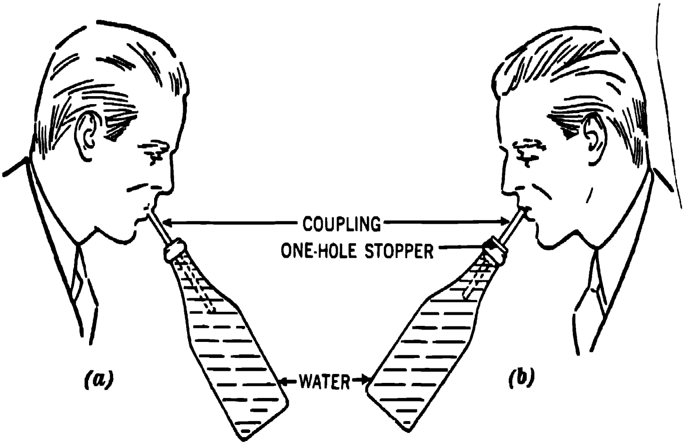
c. Hold a lighted match to the smoke producer and raise the bottle fairly rapidly but keep its bottomless end under water.
The bottle will draw in smoke.

d. Remove the stopper and lower the bottle.
The bottle will puff out smoke.

To make a paper smoke producer.

e. *f*. Cut a 4″ x 4″ piece of newspaper and roll one edge around a match.

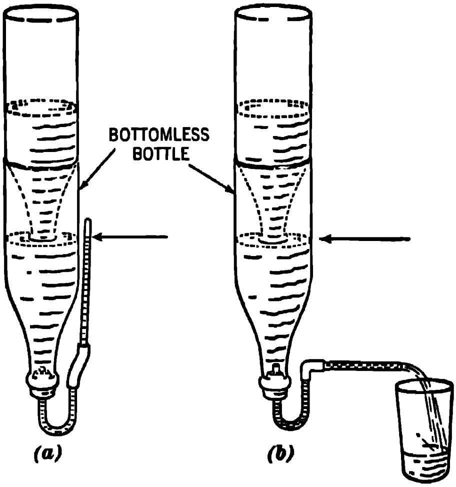
g. *h*. *i*. Remove the match. Roll the smoke producer, place it in the large union, and let it unroll to fit the union. Glue the last half inch, roll it, and let it dry over night.



136. You Can and You Cannot

a. You can suck water from the bottle.

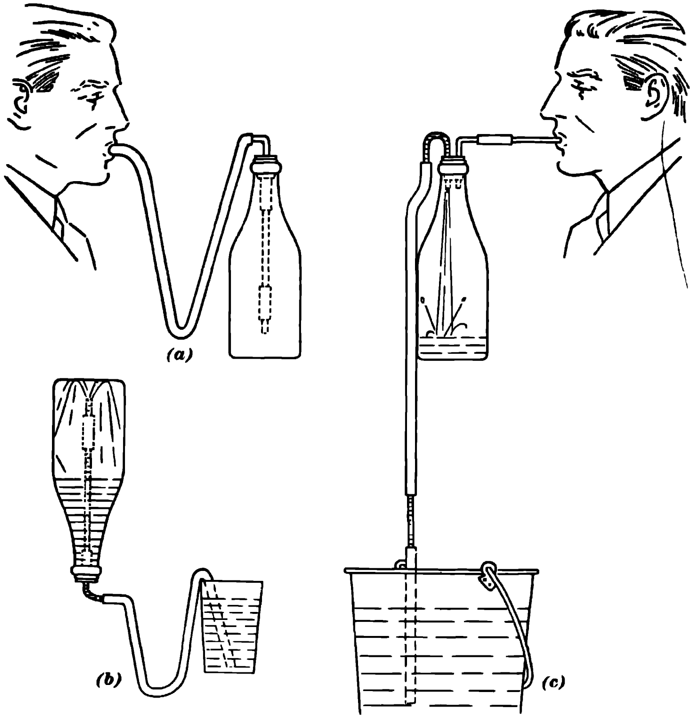
b. You cannot suck water from the bottle, if it is *full* of water and *closed* by a one-hole stopper through which the coupling passes.



137. A Drinking Fountain

a. Arrange the bottomless bottle and invert into it a whole bottle full of water. The water will stop running when its surface reaches the mouth of the upper bottle.

b. Run water into a tumbler. Air will enter the upper bottle and water will leave it; but the water surface in the bottomless bottle will remain nearly at the level of the mouth of the upper bottle, until the upper bottle is empty.



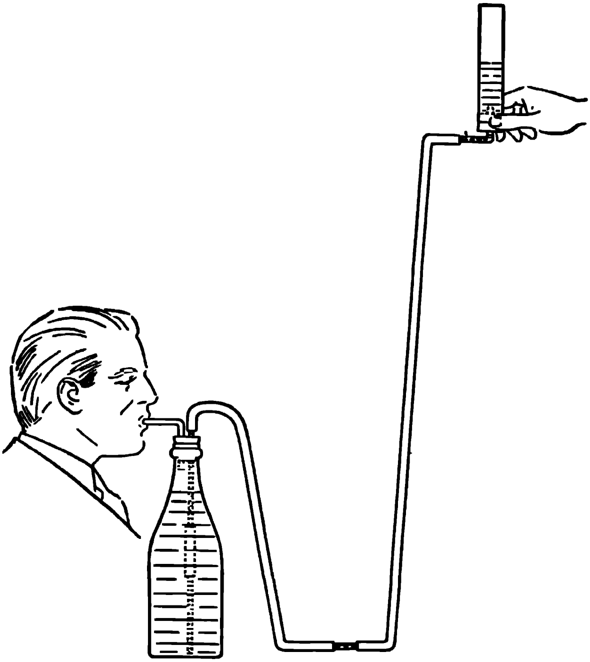
138. To Test Your Suction

a. Suck air out of the bottle, pinch the tube, rest, suck out more air, and repeat until you cannot remove more air.

b. Release the pinched tube under water.

The volume of water which enters equals the volume of air removed.

c. Test how *high* you can suck water.

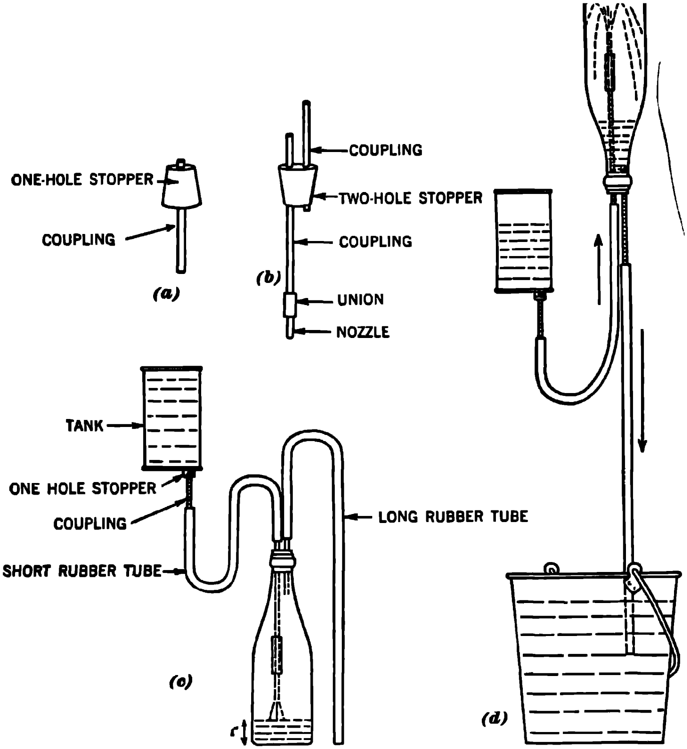


139. To Test Your Lung Force

Blow into the bottle while a friend raises the large glass tube until the water in the tube begins to move downward.

The height in feet from the water surface in the bottle to that in the large glass tube is your lung force in feet of water.

Do not overdo it. You might injure your lungs.



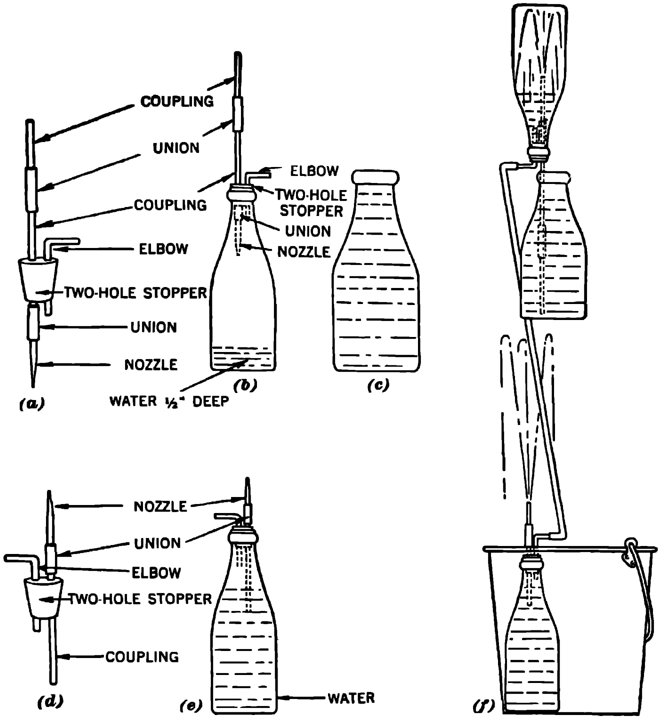
140. The Water Rises Above its Source

a. b. Arrange the equipment.

c. Fill the tank with water and run water into the bottle to a depth of one inch.

d. Invert the bottle above the tank but keep the lower end of its long tube under water in a pail.

You will see a fountain in the bottle although it is above the water level in the tank.

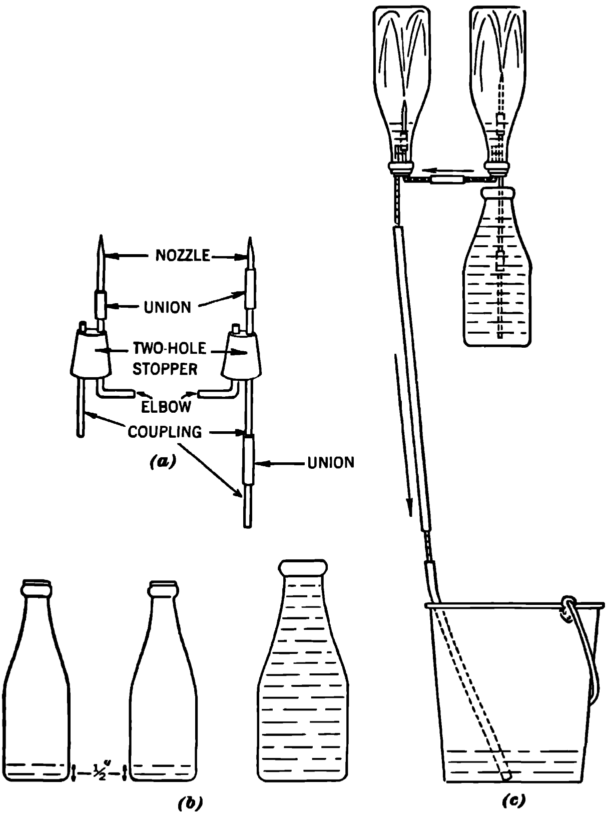


141. Two Fountains

a. b. c. d. e. Arrange the equipment.

f. Connect the bottles with the long rubber tube. Invert the upper bottle, put the lower coupling in the milk bottle, and hold them as high as the rubber tube will permit.

You will see two fine fountains.

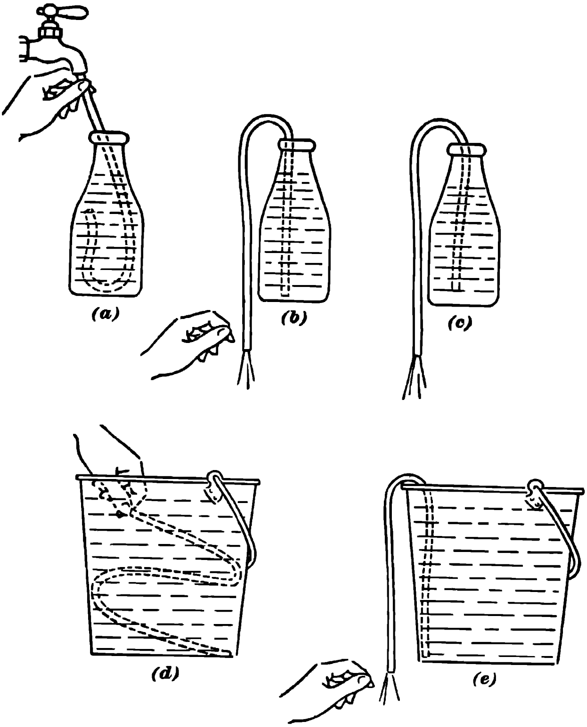


142. A Double Fountain

a. Arrange the equipment.

b. Pour water into the bottles as indicated.

c. Make the test and you will see a fine fountain in each soda bottle.



143. Various Ways of Starting a Siphon

To start a siphon, you must fill the tube with the liquid to be siphoned and thereby expel the air from it.

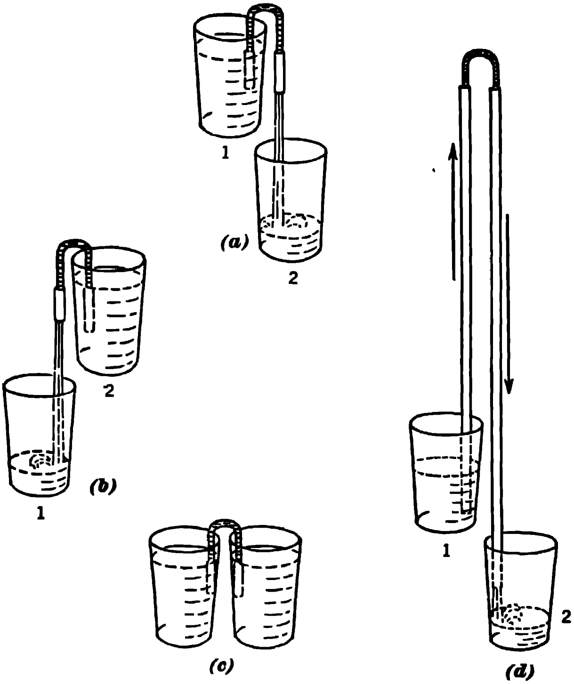
a. Fill the bottle and pinch the end of the tube.

b. Release the end when it is lower than the water surface in the bottle and the water will flow.

c. Suck air from the outer end of the tube when it is lower than the water surface and the water will flow.

d. Sink the tube under water, being sure to keep the part in water lower than the part just entering the water.
Pinch the end and draw the tube partly out of the pail.

e. Release the end when it is lower than the water surface in the pail and the water will flow.



144. Short and Long Siphons

a. Siphon water from 1 into 2.

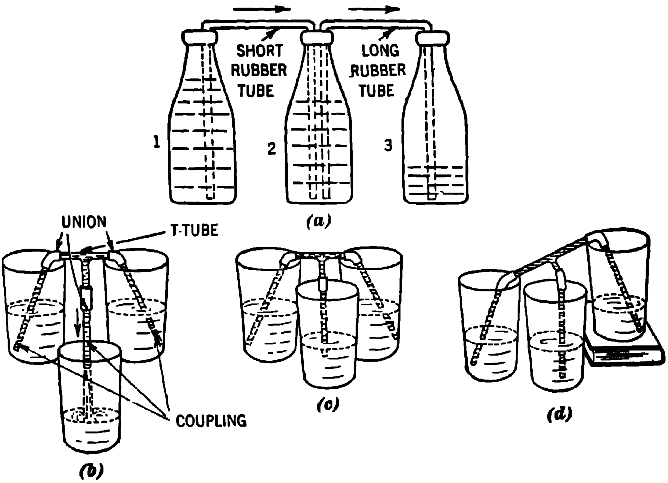
b. Before the flow stops, lift 2 above 1.

The water will flow in the opposite direction.

c. Stand the tumblers side by side.

The flow will stop when the water levels are the same.

d. Repeat *a*, *b*, *c* with the long siphon.



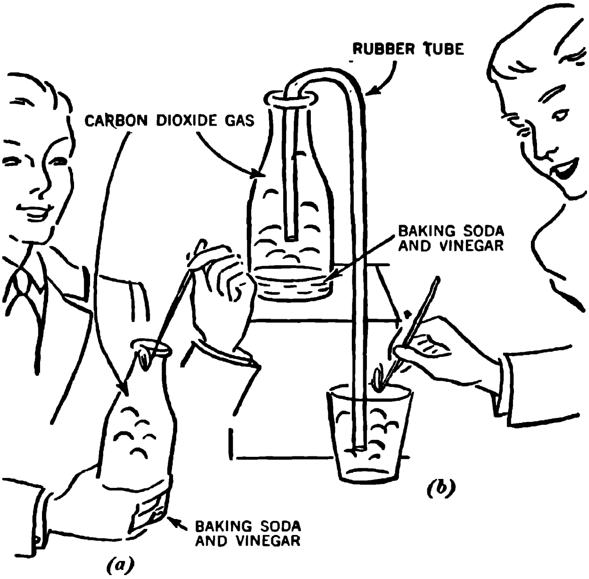
145. A Double Siphon and a Three-Legged Siphon

a. Siphon water from 1 to 2 and from 2 to 3.

The flow is always from the higher to the lower water level and it stops when the water levels are the same.

b. Arrange a three-legged siphon.

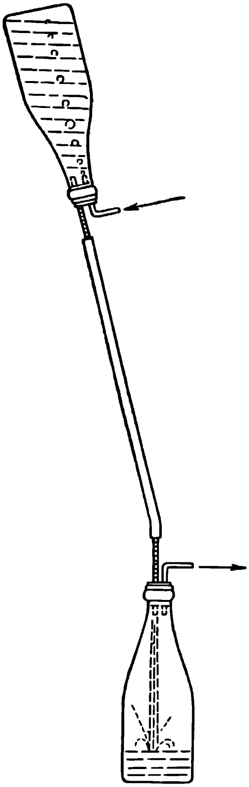
c. and *d.* The flow is always from the higher to the lower water level and it stops when the water levels are the same.



146. You Siphon Gas

a. Put a heaping teaspoonful of baking soda in a quart milk bottle and add, a little at a time, a quarter-cup of vinegar. The soda and vinegar will fill the bottle with heavy carbon dioxide (CO_2) gas. Test the gas with a burning splinter and you will see the gas put out the fire.

b. Shove one end of a rubber tube into the bottle until it is just above the liquid. Lower the other end of the tube below the bottom of the bottle, give it a strong suck, and place it in a tumbler. Test the gas in the tumbler with a burning splinter and the gas will put out the flame. This shows that you have siphoned gas out of the bottle and into the tumbler.



147. Air Pressure and Suction

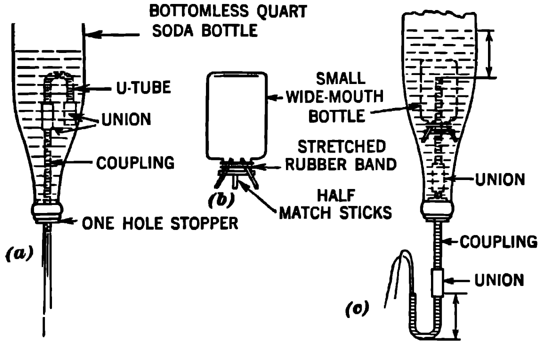
Arrange the equipment.

Fill the upper bottle with water, invert it, and slant it away from its elbow.

Hold your finger near the upper elbow and you feel suction.

Hold it near the lower elbow and you feel air pressure.

Invert the whole equipment when the upper bottle is empty and the lower full, and repeat.



148. Automatic-Discharge Siphons

a. Pour water slowly into the bottomless bottle.

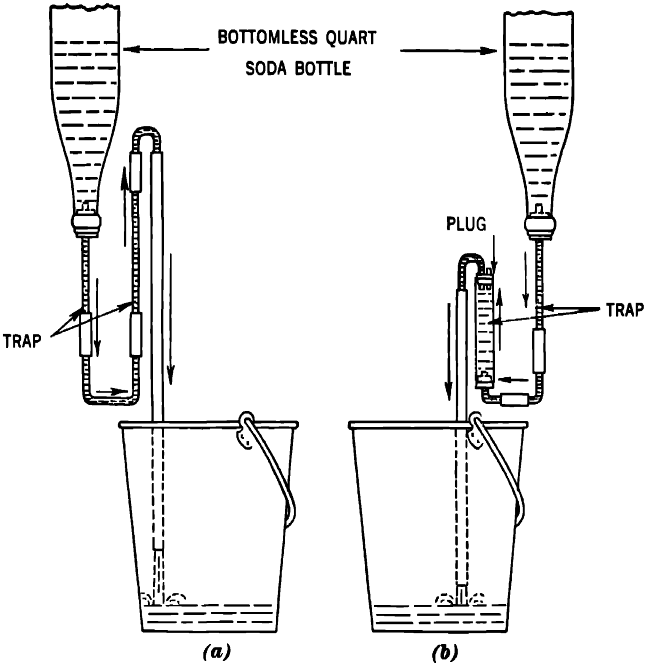
The discharge will start when the U-tube is covered.

b. Attach three half-matches to the neck of a small wide-mouthed bottle, with a stretched rubber band.

c. Pour water slowly into the bottomless bottle.

The first discharge will start when the water is above the upper coupling.

All later discharges will start only when the water is above the upper coupling a distance equal to the depth of the U-tube.



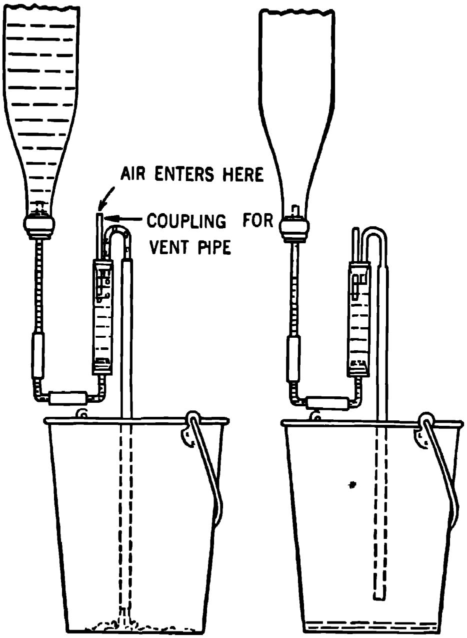
149. Siphon Traps

a. Trap with small equal arms. Pour water into the bottomless bottle.

The trap will be nearly *empty* after the discharge stops.

b. Trap with large middle arm. Pour water into the bottomless bottle.

The trap will be nearly *full* after the discharge stops.



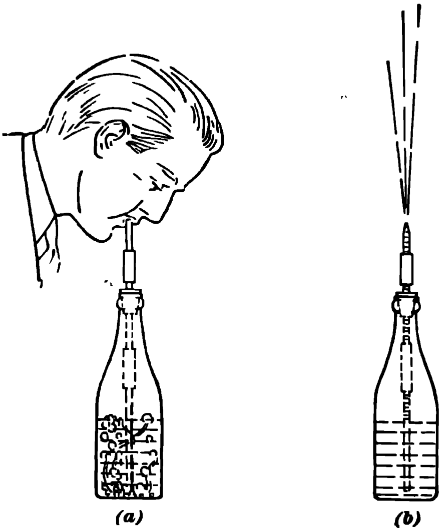
(a) (b)

150. A Siphon Trap with a Vent Pipe

a. Pour water into the bottomless bottle and let it discharge.

Air will be drawn in through the vent pipe.

b. After discharge the trap will be nearly *full* of water.

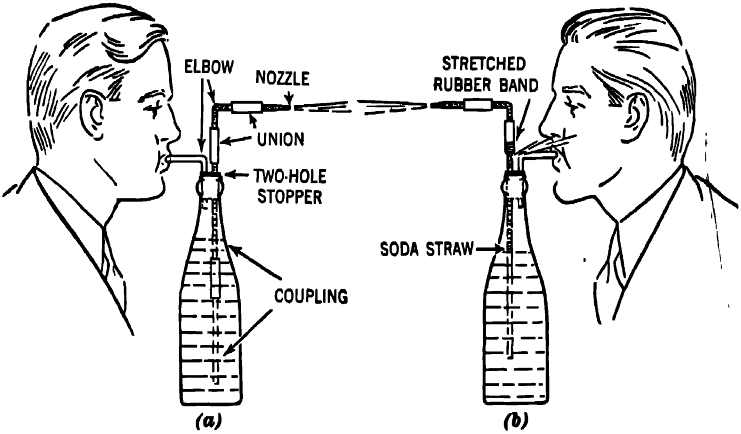


(a) (b)

151. A Fountain

a. Fill a pint soda bottle half full of water, insert the nozzle, unions, couplings, and one-hole stopper, then blow as hard as you can to force air into the bottle.

b. Jump back quickly and you will see a fine fountain.

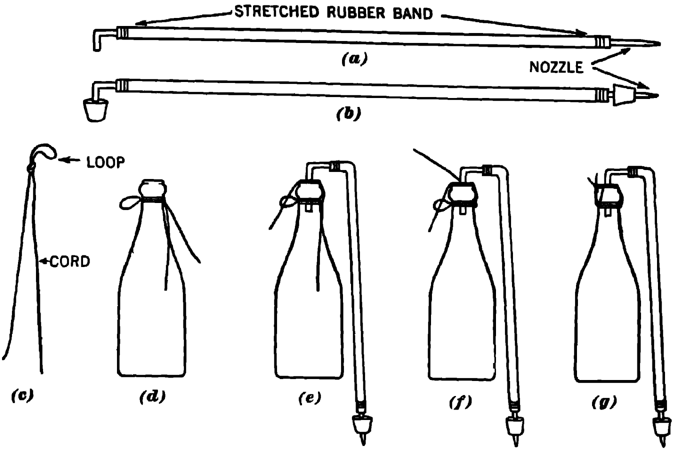


152. Squirt Bottles

a. Fill the bottle with water and blow hard into the elbow. You will produce a fine stream.

b. *Trick squirt bottle.* Use a soda straw as shown and cut a small hole near its upper end. Hold a finger over the hole and blow a long stream in front of a friend who does not know about the hole.

He will wish to try. Let him do so and tell him to blow hard. He will be surprised to find his face getting wet.



153. To Arrange a Pneumatic Tank

a. b. Arrange the equipment.

c. Cut a 26-inch length of stout cord, double it, and tie a half-inch loop in the doubled end.

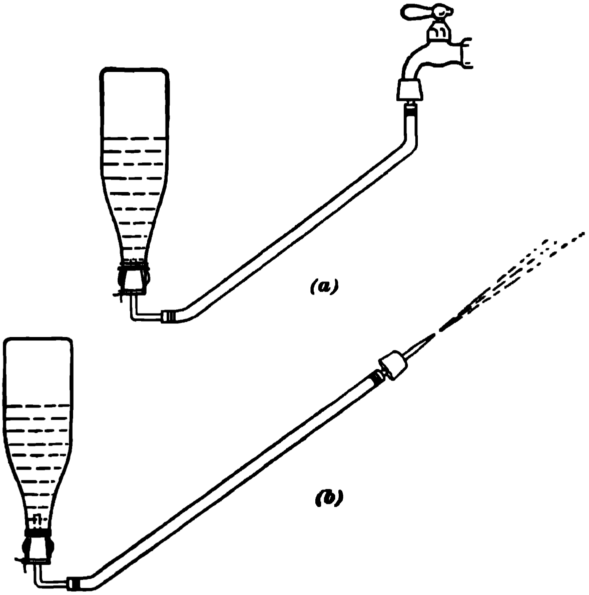
d. Pass the halves two and a half times around the neck of the bottle and tie them in a firm double knot *exactly opposite* the loop.

e. Insert the elbow stopper firmly into the mouth of a quart soda bottle, then pass one-half the cord around the elbow and through the loop.

f. Pass the other half of the cord around the elbow in the opposite direction but do not pass it through the loop.

g. Tighten the two cords and tie them firmly above the stopper to hold the stopper securely in the mouth of the bottle.

See the next experience for the use of this pneumatic tank.



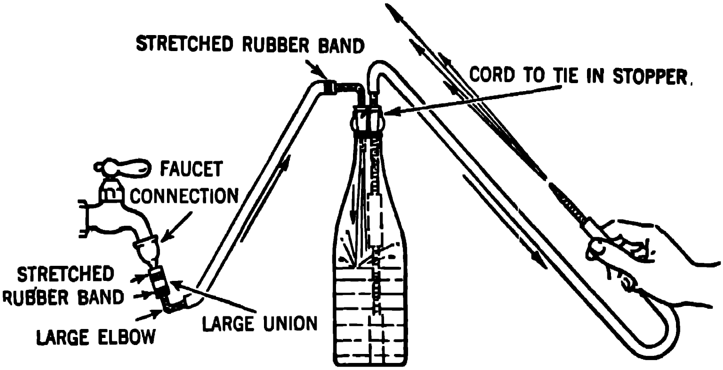
154. To Use the Pneumatic Tank

a. Let a friend hold the bottle *upside down* while you insert the end of the nozzle into the mouth of a water faucet and hold the nozzle stopper firmly against the mouth of the faucet.

Turn on the water and fill the bottle *not more than half full* of water. Squeeze the rubber tube.

b. Go to a place where you have a long range, point the nozzle at an upward angle, and release the tube.

You will see the water shoot twenty feet or more.

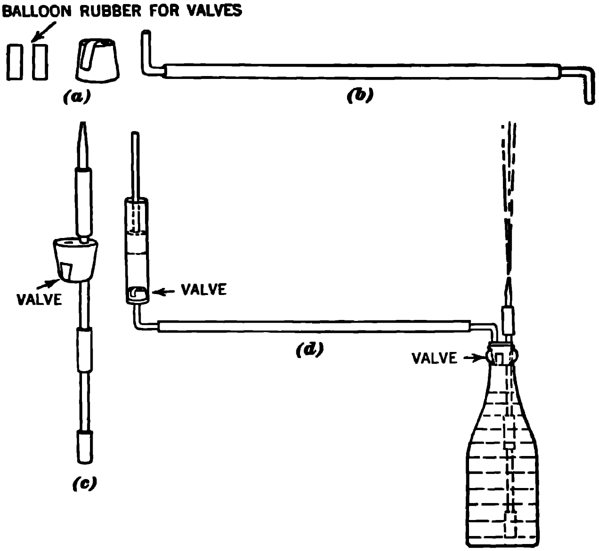


155. Air Chamber

Arrange the equipment and be particular about the stretched rubber bands (see Experience 89) and the cord to tie in the stopper (see Experience 136).

Run water into the bottle and you will get a fine stream which will continue after you shut off the faucet.

Warning. Do not let the water rise above the middle of the bottle, because the air pressure in the bottle increases very rapidly above this point.



156. An Air Pump

a. Cut two pieces of balloon rubber about $\frac{3}{8}''$ x $2''$ for valves and place one over one hole of a two-hole stopper at the small end.

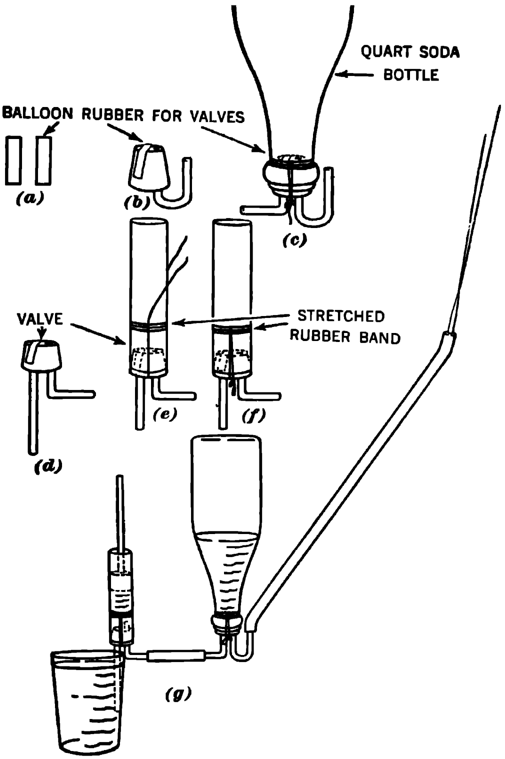
b. Fasten an elbow in each end of a rubber tube.

c. Arrange one two-hole stopper with a valve and tubing for the bottle.

d. Arrange the second two-hole stopper with a valve in a pump. Fill a quart soda bottle with water, arrange the equipment and pump air into the bottle.

You will produce a fine fountain.

Note. **See page 223 on how to make the plunger.**



157. A Force Pump

a. Cut two strips of balloon rubber about ⅜″ x 2″ for valves.

b. Place one strip over one hole of a two-hole stopper at the small end and insert an elbow and U-tube into the holes at the other end.

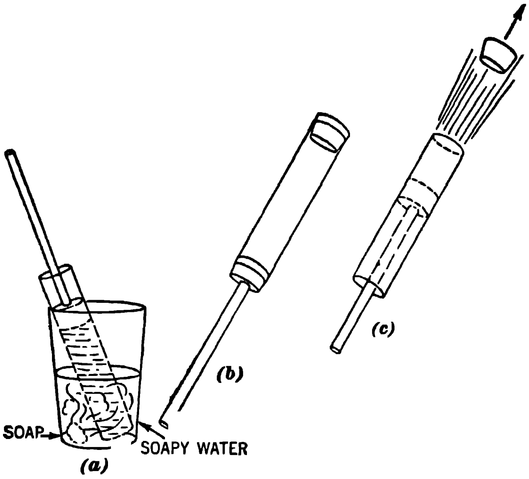
c. Tie the stopper securely into the mouth of a pint soda bottle as explained in Experience 153.

d. Place the other strip of balloon rubber over one hole in another two-hole stopper and insert a coupling and elbow into the stopper.

e. To tie this stopper into one end of the large glass tube, pull a stout cord over the stopper, and clamp the cord to the large tube with a stretched rubber band, then:

f. Tie the ends of the cord firmly under the stopper.

g. Arrange the equipment, move the plunger up and down vigorously, and you will produce a fine long stream.



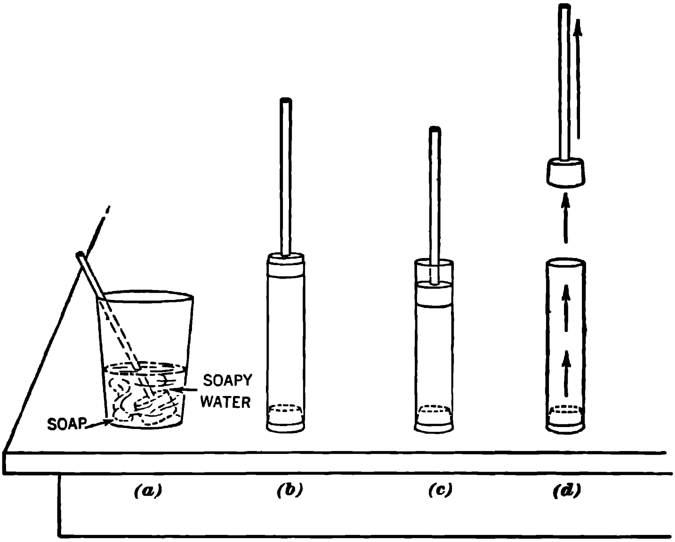
158. A Pop-Gun

a. Put a piece of soap into a tumbler half full of water and put the large glass tube into the soapy water. Move the plunger up and down to clean the tube and to make it slippery.

b. Insert the solid stopper into one end of the tube and the plunger into the other.

c. Shove the plunger in hard and the solid stopper will shoot out with a loud pop.

Note. See page 223 on how to make the plunger.



159. A Pop-Up Gun

a. Rinse the plunger in soapy water.

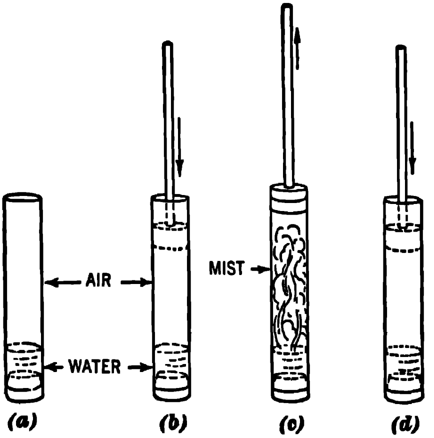
b. Hold the large glass tube upright with the solid stopper resting on the table and insert the plunger into its upper end.

c. Shove the plunger down quickly.

d. Release it quickly, and it will shoot up to the ceiling.

There is a knack to this. The secrets of success are:

1. Don't let air escape from the tube when you insert the plunger. If it does, *remove the plunger,* wet it, and try again. Expand or contract the plunger if need be.
2. Keep the plunger slippery with soapy water.
3. Shove the plunger down only about one inch until you learn the knack of it.



160. Mist

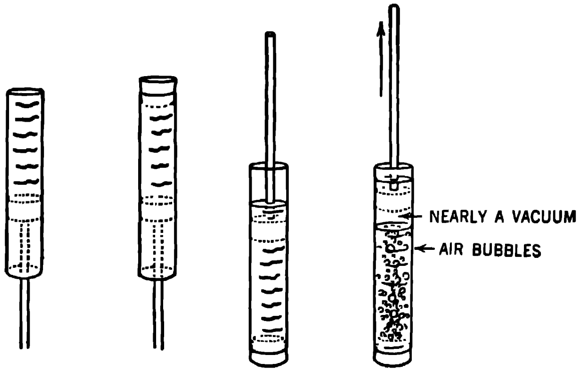
a. Insert the solid stopper into the lower end of the large glass tube and pour in about one-half inch of water.

b. Insert the plunger and shove it down.

c. Release the plunger and you will see thin mist form in the tube. You will see this best if you work with your back to the light.

d. Shove the plunger down again and the mist disappears.

Release it and the mist re-appears.



(a) (b) (c) (d)

161. To Pump Air Out of Water

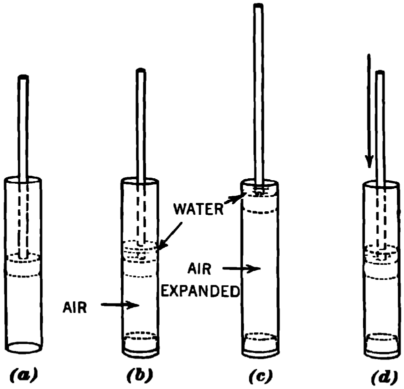
a. Shove the plunger half-way into the large glass tube and fill the space above it with water.

b. Insert the solid stopper without admitting air.

c. Invert the tube and pour water in above the plunger to make it air-tight.

d. Hold the tube and raise the plunger. You will see thousands of air bubbles come out of the water below the plunger.

Release the plunger and you will see only a small air bubble beneath the plunger.



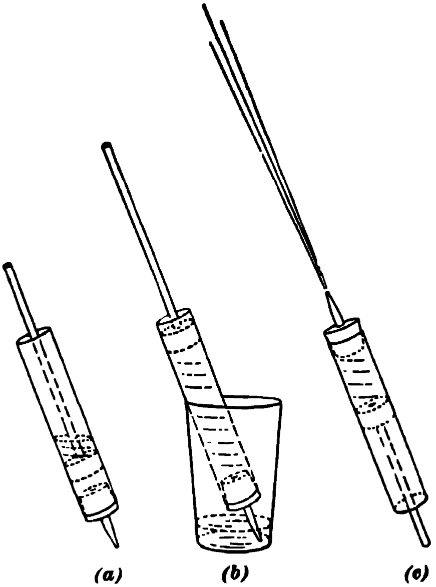
162. Expanded Air

a. Shove the plunger half-way into the large glass tube.

b. Insert the solid stopper into the lower end and pour water above the plunger to make it air-tight.

c. Hold the tube and raise the plunger.

d. Release the plunger and it will shoot back down the tube.



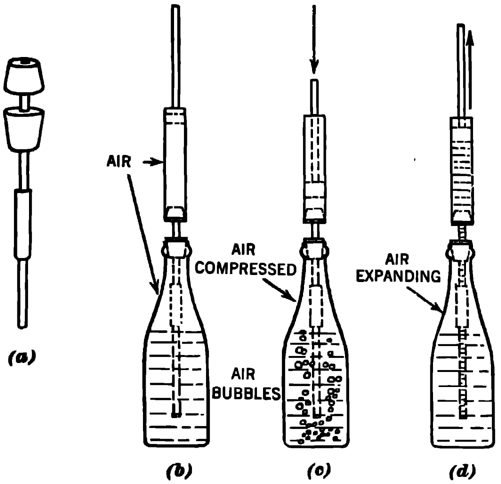
163. A Syringe

a. Insert a one-hole stopper and nozzle into one end of the large glass tube and the plunger into the other. Pour a little water above the plunger to make it airtight.

b. Dip the nozzle into water, raise the plunger, and water will fill the tube.

c. Point the nozzle upward and shove in the plunger.

You will produce a fine long stream.



164. You Appear to Change Air Into Water

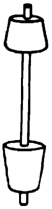
a. Pass a wet coupling through two wet one-hole stoppers and attach a union and coupling below.

b. Fill a pint soda bottle three-fourths full of water and arrange the syringe.

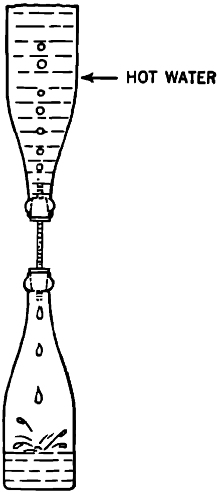
c. Hold down the bottle stopper and shove the plunger down to force air into the bottle.

d. Release the plunger and it will be raised by the water which will fill the syringe.

Note. **The plunger must be slippery.**



(a)



(b)

165. A Hiccup Bottle

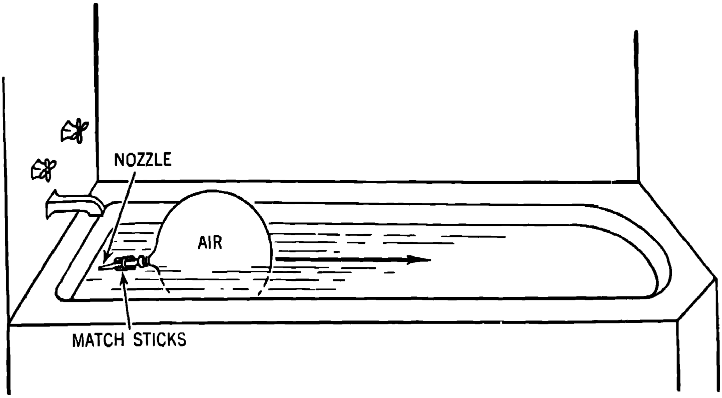
a. Pass a wet coupling through two wet one-hole stoppers making sure that its ends project slightly.

b. Connect a bottomless bottle with a whole bottle of the same size, pour *hot* water into the bottomless bottle and give the equipment a slight jerk upward.

The equipment will hiccup until the bottomless bottle is empty.

Now invert the equipment over a pail and it will hiccup until it is empty.

Note. You use hot water because it flows through the narrow coupling more readily than cold water. It is much more fluid than cold water.



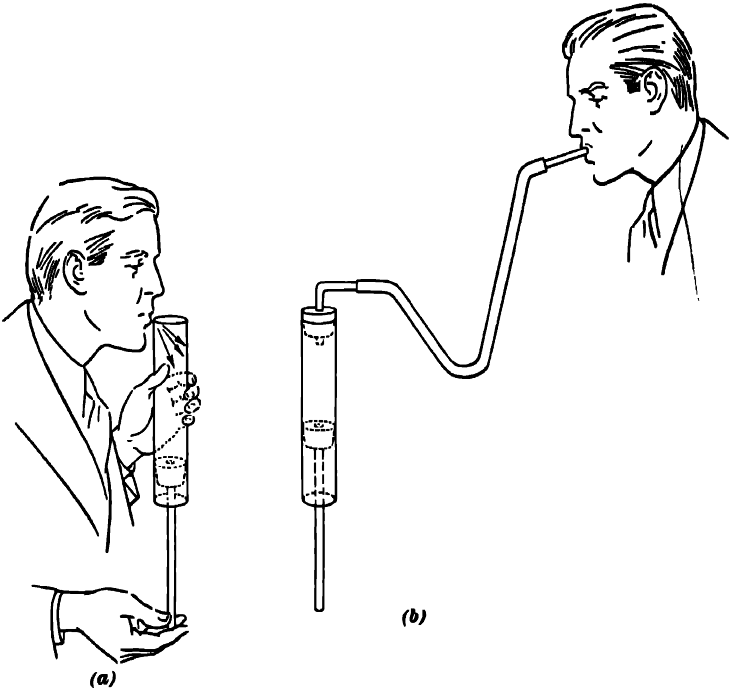
166. A Compressed-Air Boat

Fasten a nozzle in the mouth of a balloon with a stretched rubber band.

Fasten two match sticks to the nozzle with a stretched rubber band in such a way that the nozzle will be nearly horizontal and just under the water surface.

Blow up the balloon and place it on the water in a bathtub.

The compressed-air boat will sail ahead with a put-put sound.

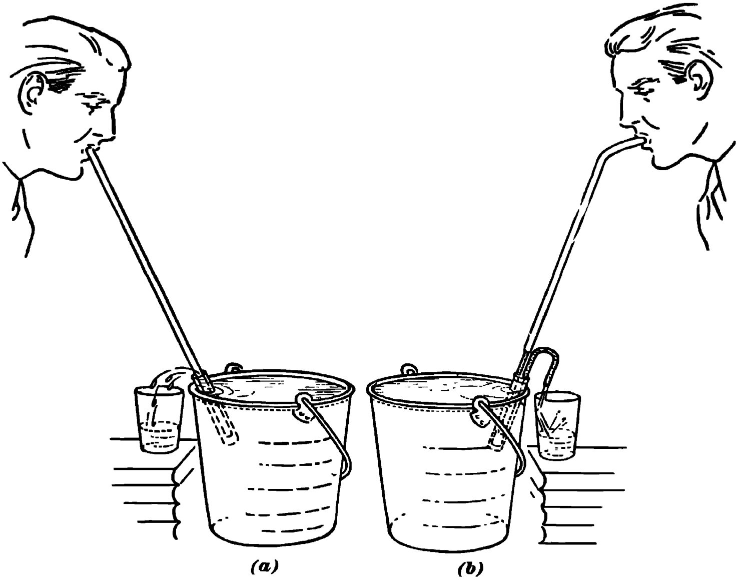


167. Diablo Whistle and Air Control

a. Diablo whistle. Wet the plunger with soapy water to make it slippery. Blow hard across the top of the large glass tube and move the plunger up and down.

You will produce weird sounds of varying pitch.

b. Air control. Suck out air and the plunger will move up. Blow in air and the plunger will move down.



168. Air-Lift Pumps

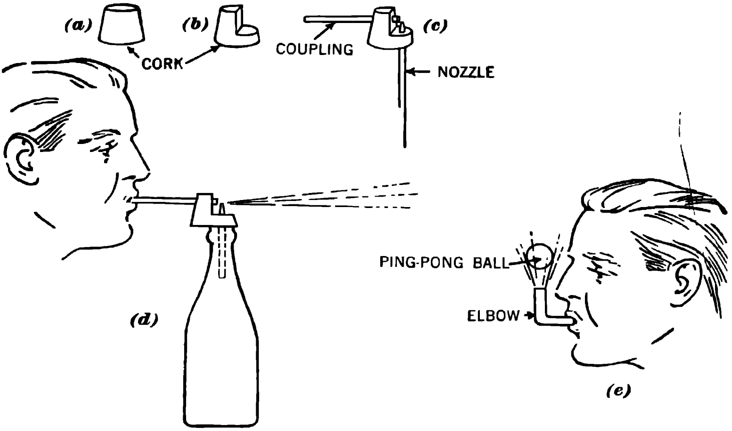
a. Place a rubber tube in the large glass tube and hold it with its lower end about three-quarters of an inch above the lower end of the glass tube.

Place both in a slanting position in a pail nearly *full* of water and blow hard into the rubber tube.

Water will rise in the glass tube and issue from the top in large gobs.

b. Arrange the equipment with the lower end of the union about ¾ inch above the lower end of the large glass tube and blow into the rubber tube.

The water will rise in the glass tube and issue from the U-tube in spurts.



169. Bernoulli Effect with Air

Atomizer.

a. Find a large cork.

b. Cut it into an L-shape and make a hole in each arm of the L.

c. Insert a coupling and nozzle in such a way that the nozzle opening is opposite the *middle* of the coupling opening.

d. Fill a bottle *full to the top* with water, insert the nozzle, and blow *hard*.

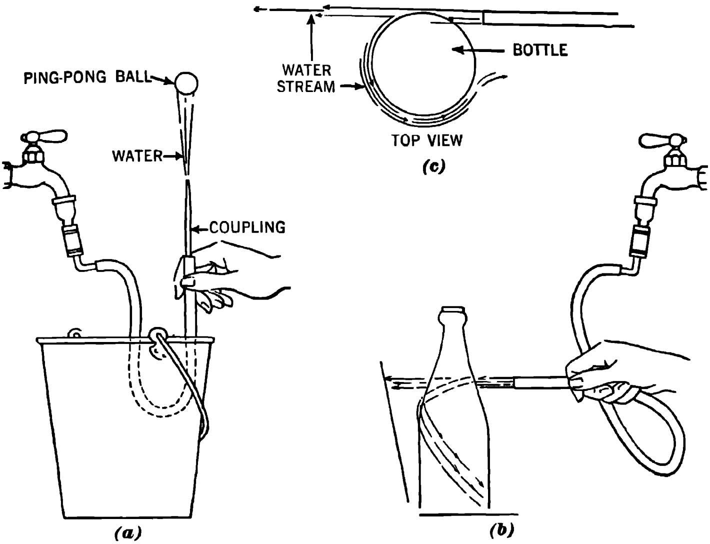
The air stream will produce a fine spray.

Ping-pong ball.

e. Blow *hard* into the elbow.

The air stream will support the ball.

See also Experiences 1 to 5 and 41 to 56.



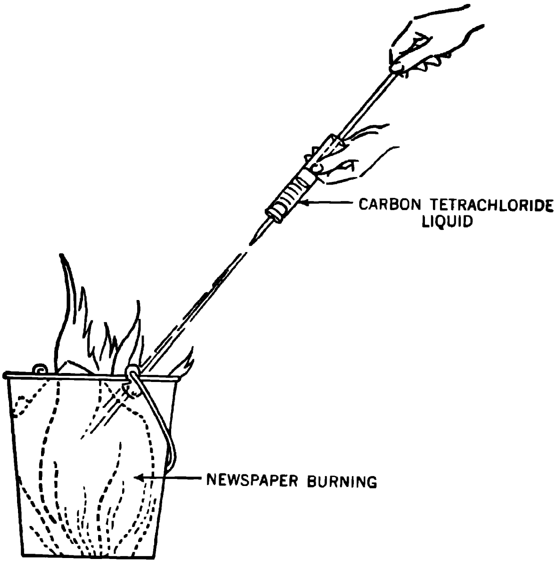
170. Bernoulli Effect with Water

a. The water stream will keep the ball bobbing up and down.

b. The water stream, which strikes one edge of the bottle, divides. Part of it goes straight ahead but part of it clings to the bottle and passes almost completely around it.

c. Top view.

See also Experiences 52 to 56.

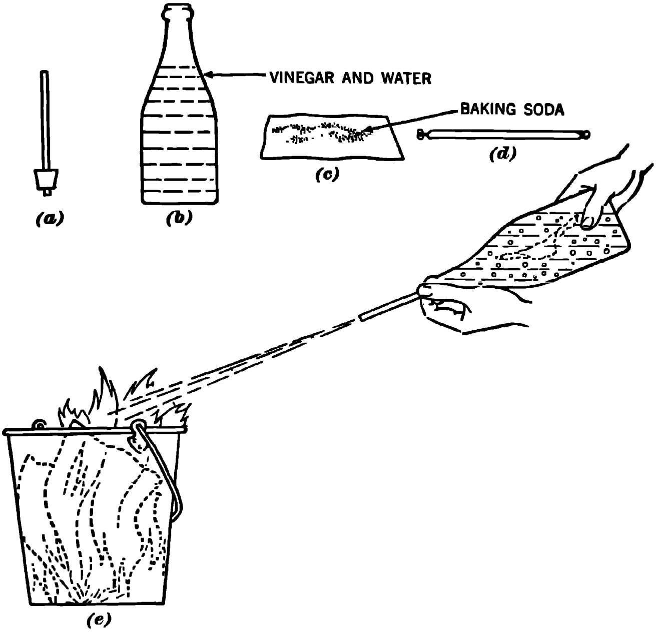


171. Carbon-Tetrachloride Fire Extinguisher

Make a syringe and fill it with carbon-tetrachloride liquid.

Crumple a single sheet of newspaper in a large pail and light it at the lower side.

When it is burning full blast, squirt carbon-tetrachloride liquid into the pail and the fire will go out.



172. Soda-acid Fire Extinguisher

a. Insert a coupling into a one-hole stopper.

b. Fill the body (not the neck) of a pint soda bottle with a mixture half vinegar and half water.

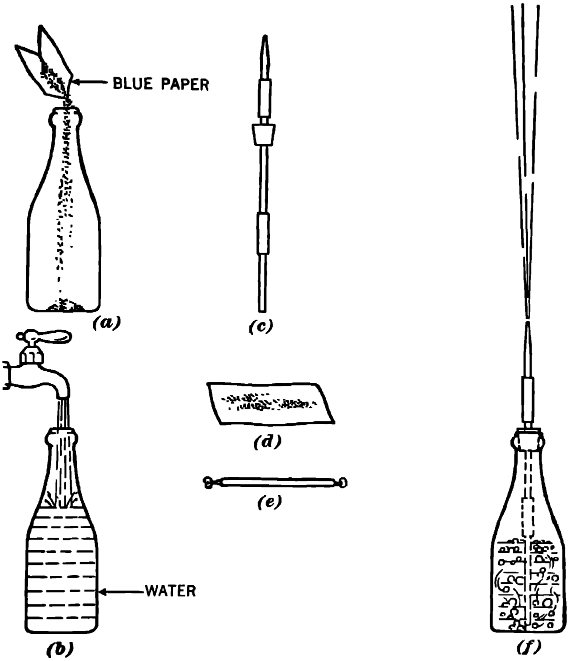
c. Spread a *level* tablespoonful of baking soda on a single sheet of toilet paper.

d. Make it into a long slender roll and twist its ends.

e. Crumple a single sheet of newspaper in a large pail and light it at the bottom.

When the flame is at its highest drop the roll into the bottle, insert the stopper and coupling, and shake the bottle vigorously to break up the paper roll.

Point the resulting stream at the fire and extinguish it.



173. A Seidlitz-Powder Fountain

Seidlitz powders cost five cents each and each consists of two powders wrapped in blue and white paper respectively.

a. Pour the powder from the blue paper into a pint soda bottle.

b. Fill the bottle with water to the bottom of the neck and shake it vigorously to dissolve the powder.

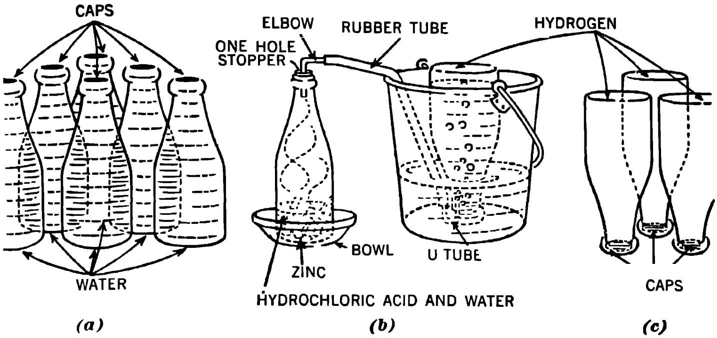
c. Arrange the one-hole stopper, couplings, unions, and nozzle.

d. Spread the powder from the white paper on a *single* sheet of toilet paper.

e. Make it into a thin roll with twisted ends.

f. Stand the bottle in the sink, drop in the roll, insert the stopper, etc., and twist it in very firmly.

Shake it vigorously and you will soon see a splendid fountain.



(a) *(b)* *(c)*

174. To Fill Bottles with Hydrogen

a. Fill six quart milk bottles with water and cap them.

b. Arrange the one-hole rubber stopper, elbow, rubber tube, and U-tube.

Invert a full milk bottle in 3 inches of water in a pail, remove the cap under water, and insert the U-tube.

Cut the zinc casing of a ten-cent flash-light battery into slices which will go into a pint soda bottle. Clean the slices thoroughly.

Pour into the pint soda bottle 2 ounces of strong hydrochloric acid and add 2 ounces of water.

Drop all the zinc into the bottle.

Insert the stopper and collect the hydrogen in the milk bottles.

c. Cap the bottles and stand them upside down on the table.

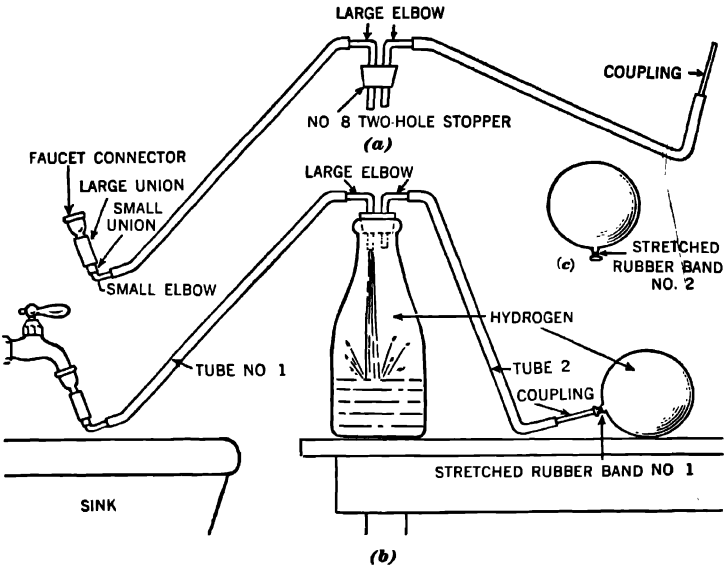
You will get 5 or 6 quarts of hydrogen.

You can prepare the hydrogen also as described in Experiences 34 and 35.

Warning. Buy the 2 ounces of strong hydrochloric acid at the drug store and ***handle it with the greatest care. Do not get any on your hands or clothes.***

Rinse out everything when you have finished.

Note. If you wish to keep hydrogen in an inverted bottle over night, leave a half inch of water in the bottle to cover the cap.



175. To Fill a Balloon with Hydrogen

a. Arrange the equipment.

b. Attach a small one-cent balloon to the coupling with stretched rubber band No. 1.

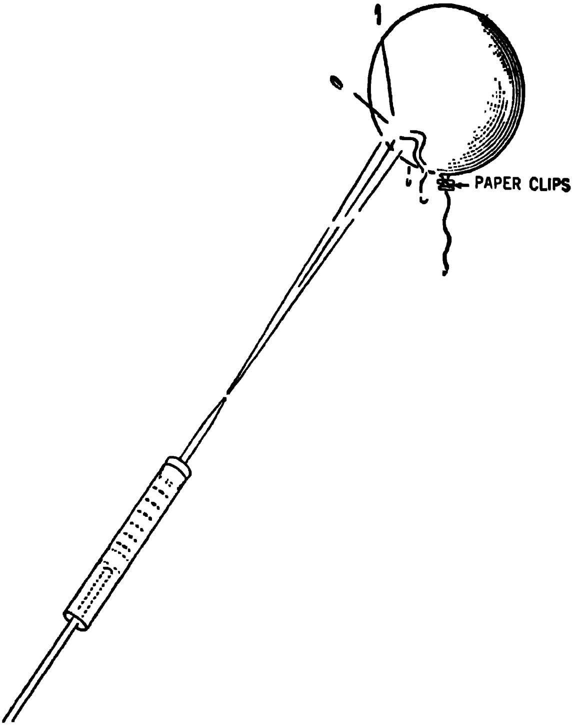
Bring a quart bottle of hydrogen from the last experience, turn it mouth down, remove the cap, insert the No. 8 stopper, and turn the bottle right side up.

Turn on the faucet and fill the bottle with water to *within one inch of the mouth and* thereby force hydrogen into the balloon.

Let one experimenter pinch tube 2 to keep the hydrogen in the balloon while a second experimenter inserts the No. 8 stopper into a second up-side-down bottle of hydrogen. Force this quart of hydrogen into the balloon and then another—3 quarts in all.

c. Close the balloon with stretched rubber band No. 2. Undo band No. 1 and release the balloon.

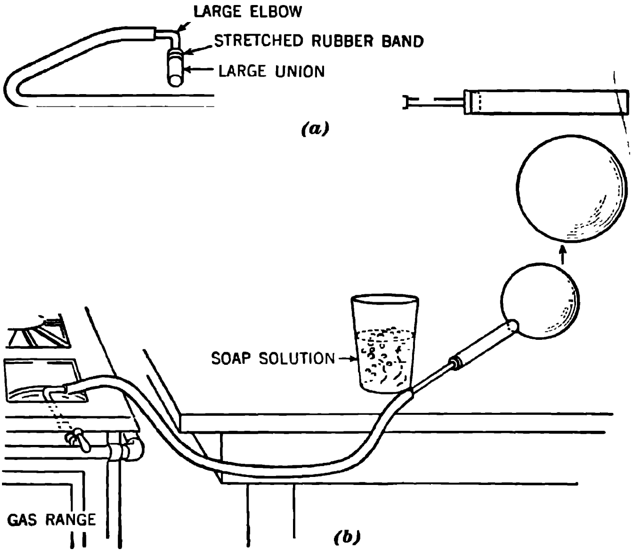
It will float up to the ceiling.



176. To Shoot Down a Balloon

Attach paper clips to the balloon until it is just floating and shoot it with a stream of water.

The balloon will sink to the floor and rise again after the water on its surface has evaporated.



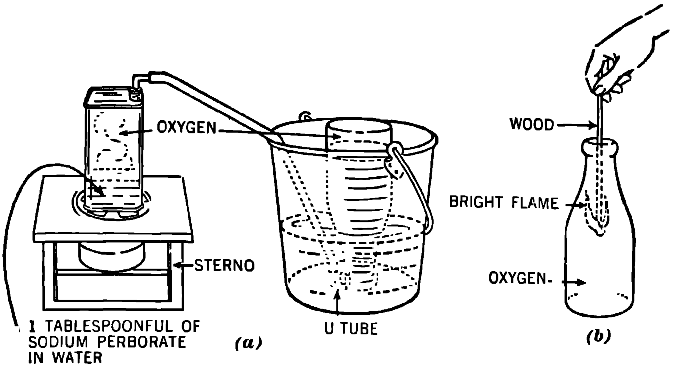
177. Bubbles Filled with Fuel Gas Float and Burn

a. Arrange the tubing.

b. Remove a burner from a gas range, shove the large union over the spud, dip the large glass tube into the soap solution, turn on the gas, blow a bubble, and shut off the gas.

c. Detach the bubble and it will float.

d. Light one end of a soda straw and touch it to a detached bubble. The gas will burn.



178. To Make and Test Oxygen

a. Measure one level tablespoonful of sodium perborate and put it into the boiler one-third full of water. Arrange the equipment and boil the water.

You will get about one quart of oxygen.

Cap the bottle and place it on the table.

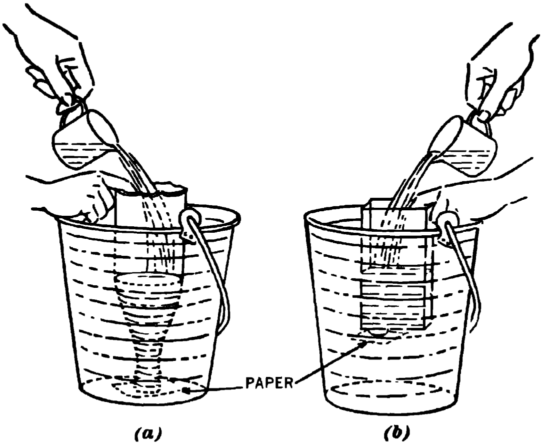
b. Light a splinter of wood at one end, let a good red live coal form, blow out the flame, and plunge the live coal end into the oxygen.

The live coal will burst into a brilliant flame.

Blow out the flame and repeat.

Rinse out the boiler thoroughly.

Note. You can buy ¼ lb. of sodium perborate at a drug store for thirty-five cents.



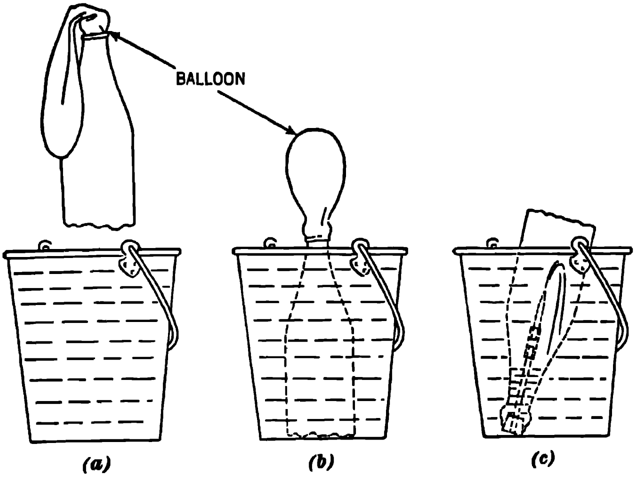
179. A Patch on a Boat

a. Hold a piece of paper over the mouth of the bottomless bottle while you sink the bottle and paper in water.

The paper illustrates a patch placed over the outside of a hole in a boat; it holds on and keeps the water out of the bottle.

Pour water into the bottle and the paper will hold on until the water level is the same inside and outside of the bottle.

b. Repeat the experience with the tank.



180. Upward Pressure

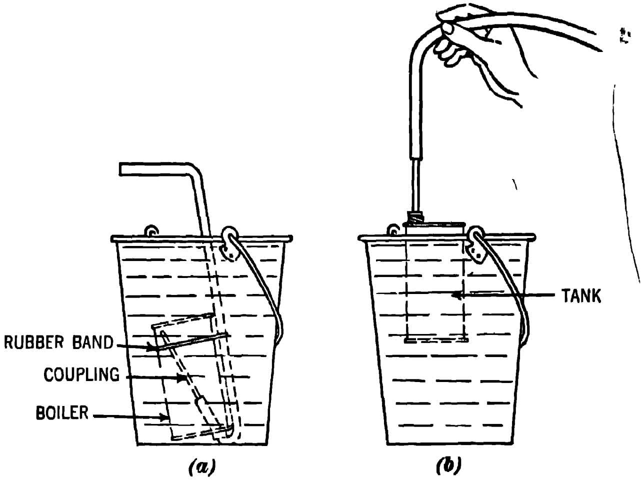
a. Blow up a balloon to stretch it, then let out the air and pull its wet mouth over the wet mouth of a quart bottomless bottle.

The balloon will droop.

b. Sink the bottle in a large pail *full* of water and the balloon will expand.

c. Remove the balloon and close the mouth of the bottomless bottle with a one-hole stopper, coupling, union, and nozzle.

Sink the bottle mouth down in a large pail *full* of water and you will see a small fountain.



181. Pontoons

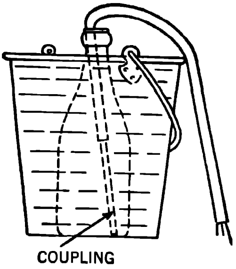
a. Arrange the boiler upside down as shown in a pail *full* of water.

Suck out air and the boiler will sink.

Blow in air and the boiler will float.

The rubber band holds the rubber tube against the outside of the boiler and thereby holds the coupling in the boiler.

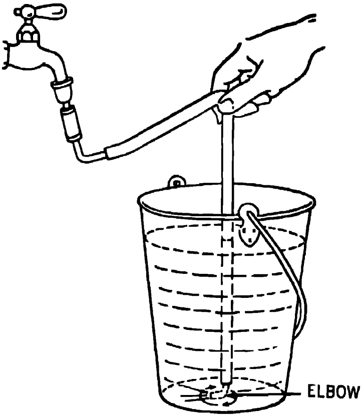
b. Repeat with the tank arranged as shown.



182. The Bottle Rises to the Surface

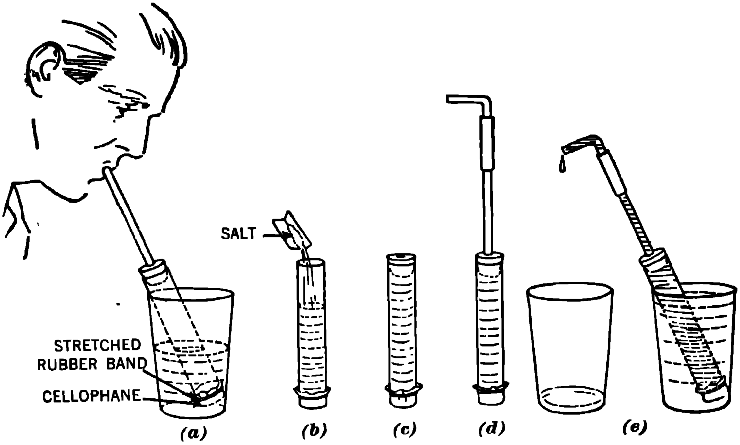
Fill a quart soda bottle with water, sink it in a pail full of water but keep its mouth above water. Place in it the long rubber tube with a coupling at one end.

Siphon water out of the bottle and it will shortly rise to the surface.



183. The Wiggler

Turn the water on full and the elbow will wiggle around violently.



184. Osmosis with Salt

a. Wet a piece of cellophane and fasten it over one end of the large glass tube by means of a stretched rubber band. Place the cellophane under water and blow gently into the tube to make sure there are no holes.

b. Fill the tube half full of water and add one heaping teaspoonful of salt.

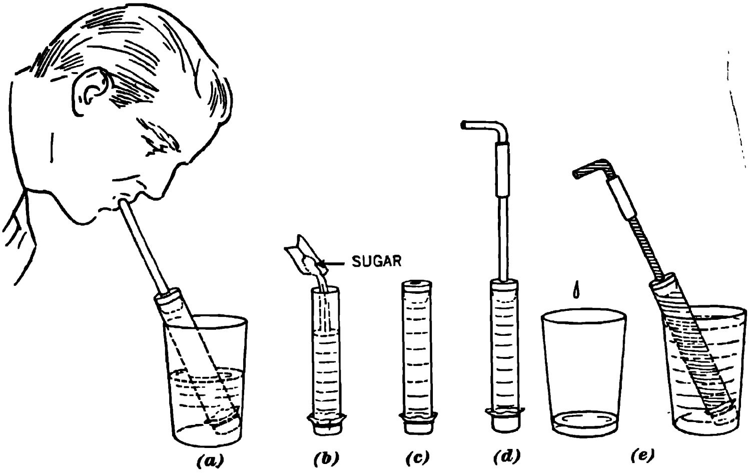
c. Fill the tube with water to the very top and twist in the one-hole stopper, being careful to let the excess water escape through the hole.

d. Twist in a coupling with union and elbow.

e. Rinse the outside of the tube and place it in a tumbler of fresh water.

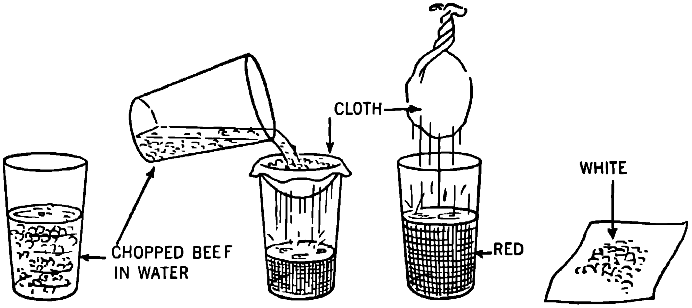
Water will rise slowly in the tube and fill the coupling, union, and elbow. Next day you will find salt water or dry salt in the second tumbler.

Note. Use the kind of cellophane in which candy is wrapped, not that in which cigarettes are wrapped. Much of the latter is made water-proof with paraffin.



185. Osmosis with Sugar

Repeat Experience 184 step by step, but use sugar instead of salt.



(a) (b) (c) (d)

186. To Get Beef Juice by Osmosis

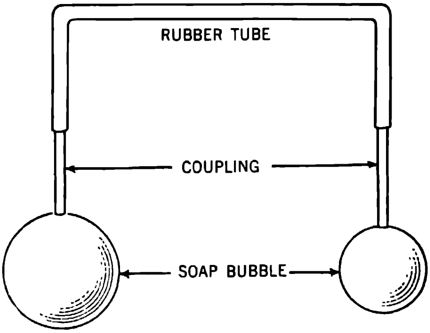
a. Buy a quarter pound of chopped red rare beef, place it in a half tumbler of water, and stir it from time to time during one hour.

b. Strain the liquid through a cloth.

c. Twist the cloth to squeeze out the last drops.

d. Open the cloth and examine the beef.

The beef juice will move into the water and leave the beef white or nearly so.



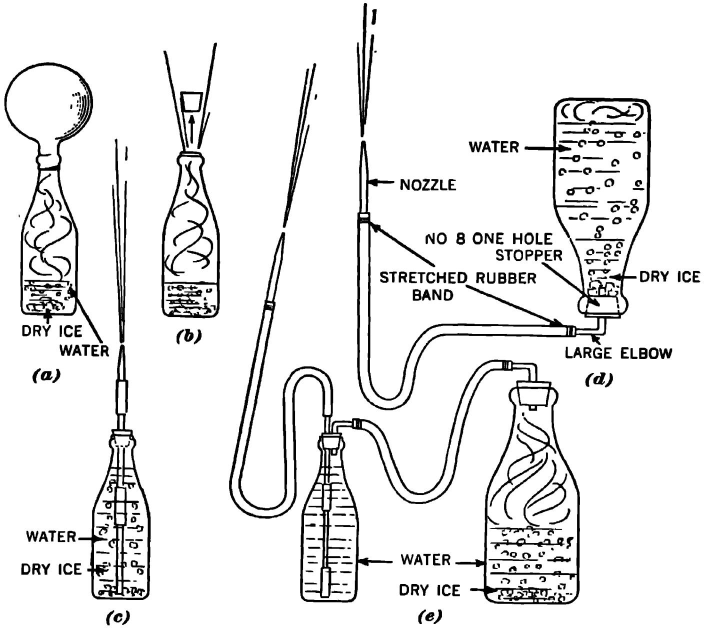
187. The Little Bubble Forces its Air into the Large One

Insert a coupling into a rubber tube and let one experimenter blow a soap bubble about 1½ inches in diameter.

Pinch the rubber to prevent the bubble from contracting.

Let another experimenter blow a soap bubble about 1 inch in diameter on another coupling and insert the coupling into the other end of the tube.

Release the pinched rubber and the smaller bubble will contract and force its air into the larger bubble.



188. Dry-Ice Pressure

a. Drop a half-dozen pieces of dry ice into water in a pint soda bottle and pull the *wet* mouth of a small balloon over the wet mouth of the bottle. The balloon will expand.

b. Insert a solid rubber stopper into the mouth of the bottle. The stopper will be driven out with a loud pop.

Warning 1. Do not shove the stopper in too firmly or the bottle may explode.

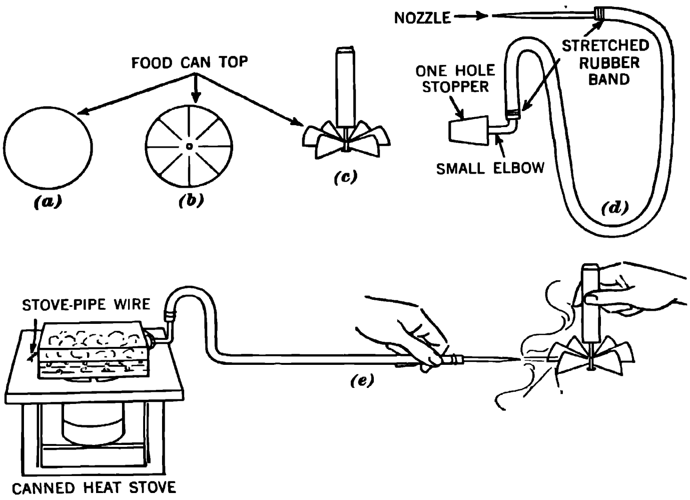
Warning 2. Never try to confine dry ice. Its gas exerts a pressure of over 1,000 lb. per sq. in. at ordinary temperatures and it will burst anything except a strong steel tank.

c. Make the test and you will see a vigorous fountain.

d. You will see a fine fountain.

e. You will see a fine fountain.

See also Experiences 109 and 110.



189. A Steam Turbine

a. Cut the round top out of a tin food can.

b. Punch a nail hole at the exact center and cut eight radial slits to within one-half inch of the hole.

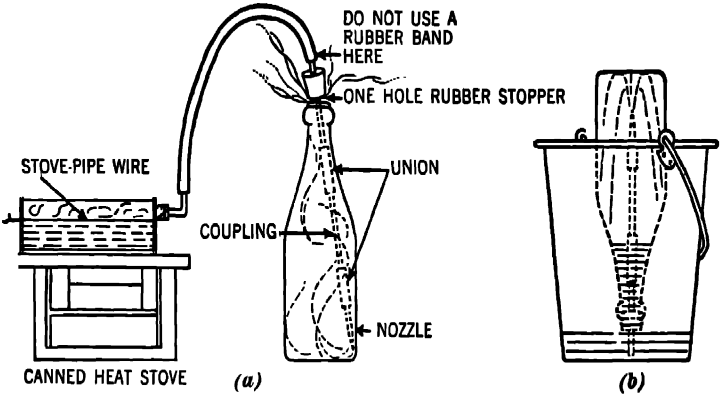
c. Attach the turbine to a wooden support by means of a nail smaller than the hole. Bend each section to make the blades of the turbine.

d. Attach an elbow and a nozzle to a long rubber tube by means of stretched rubber bands and insert the elbow into a one-hole stopper.

e. Fill the boiler *half full* of water. Insert the stopper firmly and *fasten it securely* by means of a 20-inch length of stove-pipe wire. Pass the wire once or twice around the elbow, then around the end of the boiler, and twist its ends together.

Get up steam and let it strike the rim of the turbine. It will spin the turbine at very high speed.

Warning. **Do not use too much heat. Too great steam pressure might burst the boiler.**

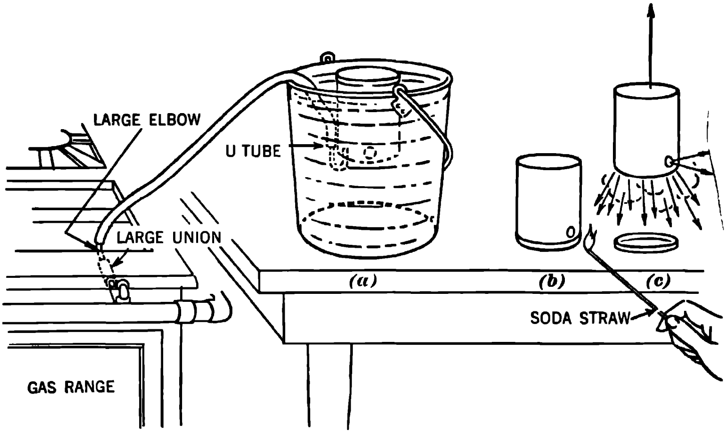


190. A Fountain

a. Arrange the equipment, but do not use a rubber band on the rubber tube just above the bottle stopper. Steam the inside of the quart soda bottle for one minute, with the stopper *outside* the bottle.

b. Pour *warm* water into the pail and quickly (1) put out the fire; (2) insert the stopper; (3) detach the tube and (4) invert the bottle into the water in the pail.

You will see a vigorous fountain in the bottle.



191. The Principle of the Gas Engine

a. Punch a half-inch hole in the side of a coffee can, just under the cover.

Place the uncovered can in a pail of water, fill it with water, turn it mouth down and pass fuel gas into it until it floats *with the bottom about ¾ inch above water.* Shut off the gas.

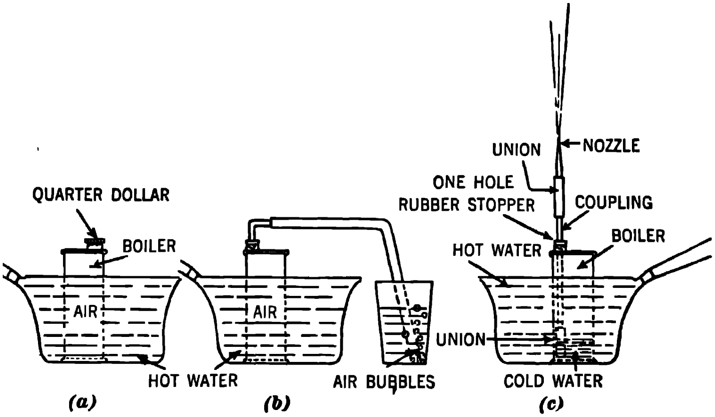
Raise the can slowly up-side-down to let air in and water out.

b. Put on the cover, stand it top-down on the table, and insert the lighted end of a soda straw into the hole.

c. The can will soar upward.

Note 1. To get gas into the can you may need to raise the can and U-tube because the gas pressure is equal to only about 3 inches of water.

Note 2. Do not use too much gas. If you do it will merely burn without exploding.



192. Air Expands when Heated

a. Wet a quarter dollar thoroughly with saliva, place it over the mouth of the boiler, and lower the boiler into hot water.

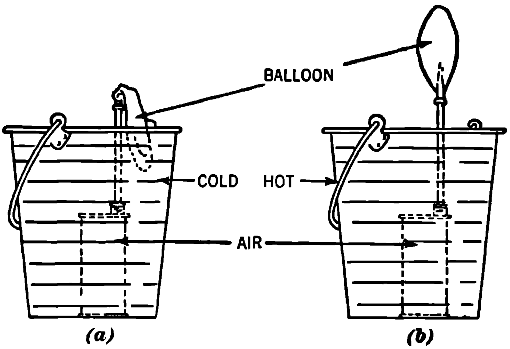
The quarter dollar will "click," "click."

b. Cool the boiler, arrange the equipment, and lower the boiler into hot water.

You will see many air bubbles.

c. Fill the boiler one-third full of cold water, arrange the equipment, and lower the boiler into hot water.

You will see a fine cold-water fountain.

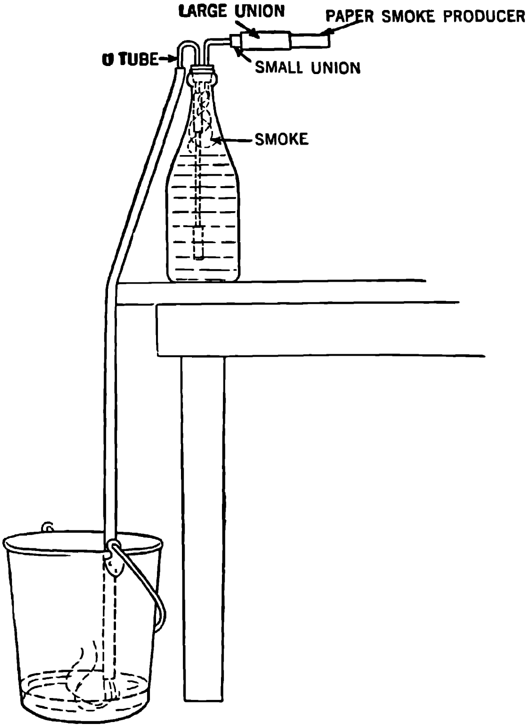


193. The Balloon Shrinks and Swells

a. Fasten a small stretched one-cent balloon to one end of a coupling with a stretched rubber band. Insert the coupling into a one-hole stopper and the stopper into the empty boiler.

Hold the boiler in cold water and the balloon will shrink.

b. Hold the boiler in hot water and the balloon will swell.

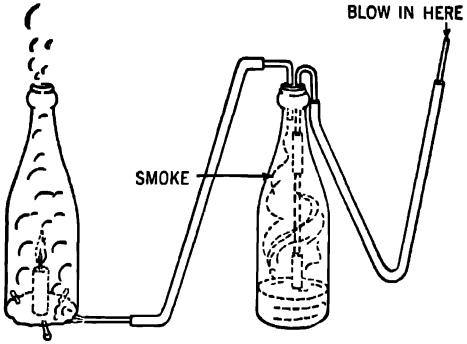


194. To Fill a Bottle with Smoke

Make a paper smoke producer as in Experience 135.

Fill the bottle with water, start the siphon, and hold a lighted match at the end of the paper.

You will see the bottle fill with smoke to the end of the siphon in the bottle.



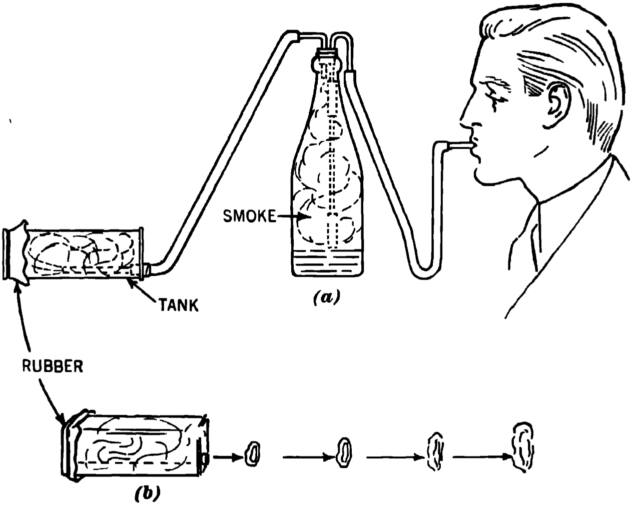
195. Convection in Air

Fill a bottle with smoke as in Experience 194 and arrange the rubber tubing as shown.

Place a lighted candle in a bottomless bottle and support the bottle a little above the table on three match sticks.

Blow smoke gently under the bottle and you will see a strong upward current of smoke and air in the bottle. Try to blow smoke gently down into the mouth of the bottle.

You will again see a strong upward current.



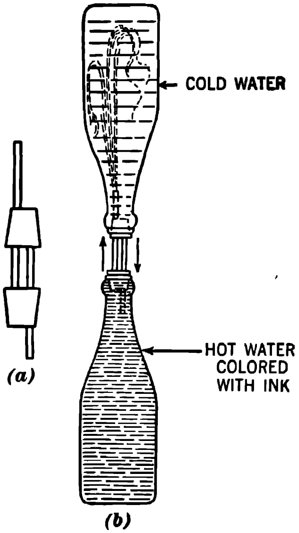
196. Vortex Smoke Rings

a. Fasten a half balloon over the open end of the tank with a stretched rubber band and *fill* the tank with smoke.

b. Tap the balloon rubber gently.

You will produce a beautiful smoke ring at each tap.

See also Experience 69.



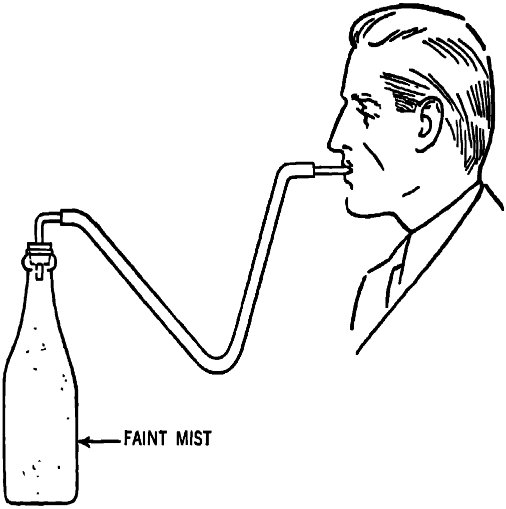
197. Convection in Water

a. Join two wet couplings and two wet two-hole stoppers in such a way that one coupling projects beyond each stopper.

b. Pour two tablespoonfuls of ink into a quart soda bottle and fill the bottle with *hot* water.

Fill another quart soda bottle with cold water without ink, close it with the coupled two-hole stoppers, and invert it over the hot bottle.

A stream of colored water will rise into the upper bottle.



198. Mist

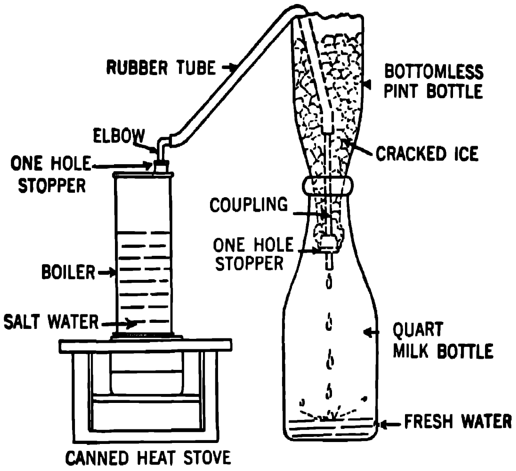
Wet the inside of a quart soda bottle with water.

Arrange the equipment, turn your back to the light, and suck air out of the bottle.

A faint mist will appear in the bottle.

Let in air and the mist will disappear instantly.

Suck out air and the mist will appear again.



199. To Get Fresh Water From Salt Water

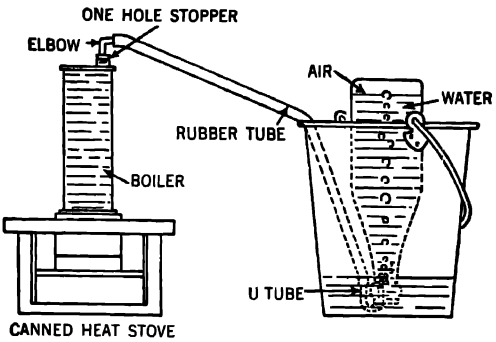
Put two tablespoonfuls of table salt into a tumbler of water and stir it.

Pour the salt water into the boiler until it is half full.

Arrange the equipment and boil the water.

Taste the water in the milk bottle and you will find it free from salt.

It is distilled water.



200. To Measure the Air in Drinking Water

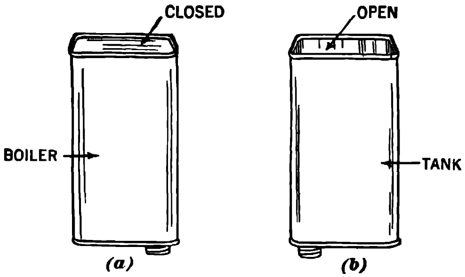
Fill the pint boiler to the very top with cold drinking water.

Fill a pint soda bottle with cold water and invert it in water in a pail. Fill the rubber tube with water.

Arrange the connecting tubes and light the burner. Run the test until you hear the cracking of steam bubbles at the mouth of the U-tube.

The air from the pint of water in the boiler will accumulate in the pint soda bottle.

Your Special Equipment



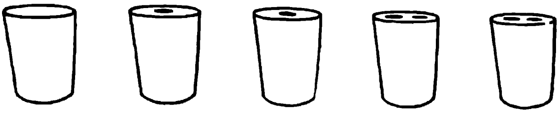
1. Boiler and Tank

a. The boiler is a pint rectangular or cylindrical metal can with a screw top ¾-inch *inside* diameter.

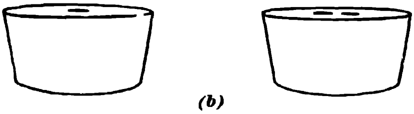
This screw top holds all No. 2 rubber stoppers.

b. The tank is a similar can with the bottom cut out.

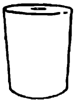
Note. Empty cylindrical pint gasoline and benzine cans are excellent.



(a)



(b)



(c)

2. Rubber Stoppers

a. Five rubber stoppers, size No. 2, one solid, two with one hole and two with two holes.

These fit the boiler, tank, large glass tube, all soda and vinegar bottles with crimp metal caps, and many common bottles.

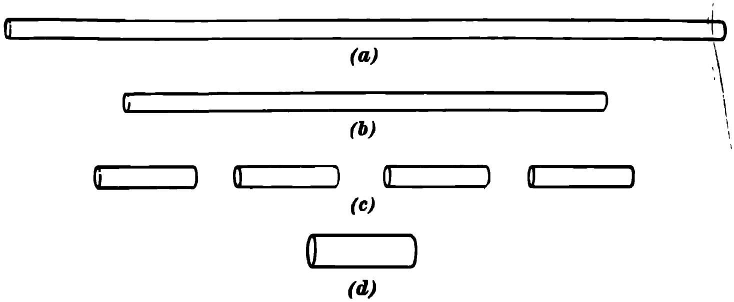
Their holes fit No. 2 glass tubing.

b. Two rubber stoppers, size No. 8, one with one hole and one with two holes. See Note, page 223.

These fit pint and quart milk bottles and their holes fit the plug and the large elbows.

c. One rubber stopper with one hole to be used for a plunger. The size is either No. 0 or No. 1 according to the inside diameter of the large glass tube. See also Your Equipment 10.

Note. **Buy the best rubber stoppers. They do not stick so tightly to glass tubing as do cheap stoppers.**



3. Rubber Tubing

a. Long rubber tube, No. 2, 30 inches long.

b. Short rubber tube, size No. 2, 20 inches long.

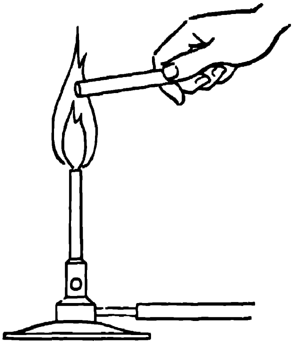
c. Four rubber unions, size No. 2, 2 inches long.

These fit all couplings, elbows, nozzles, the U-tube, the T-tube, and the plug.

d. One large rubber union, size No. 4, 2 inches long. This fits air-tight over the rubber tubes and the unions and also over a smoke producer.

Note. Buy the best rubber tubing. It does not stick so tightly to glass tubing as does cheap rubber tubing.

(a)



(b)

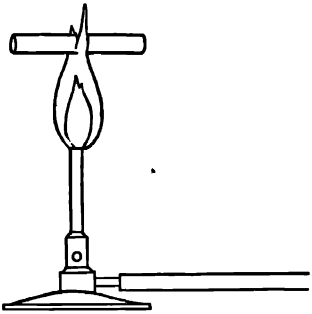
4. Glass Couplings

a. Cut four pieces of No. 2 glass tubing, 5½ inches long.

b. Smooth each end by turning it in a Bunsen flame, *above the green cone,* until it begins to be red. These fit the long rubber tubes, the unions, and the holes in the No. 2 rubber stoppers.

Note. **The end of a glass tube will contract if you heat it too long. If this happens let the end cool, shorten it ¼ inch, and anneal it again.**

(a)



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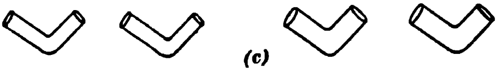


(c)

5. Small and Large Glass Elbows

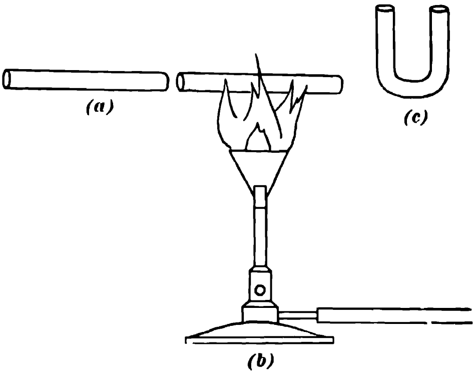
a. Cut four pieces of glass tubing 3 inches long, two from No. 2, and two from No. 4 glass tubing. Smooth the ends as in the previous experience.

b. Turn each in a Bunsen flame above the green cone until it is soft, and

c. Bend it at right angles.

The small elbows fit the holes in the No. 2 stoppers, the large, those in the No. 8 stoppers.

Both fit the rubber tubes and unions.

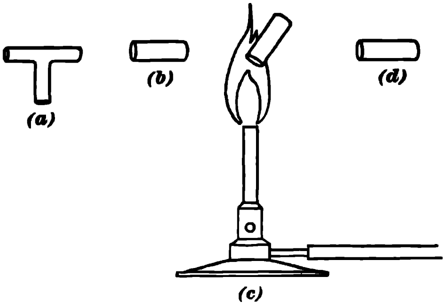


6. Glass U-Tube

a. Cut a piece of No. 2 glass tubing 5 inches long and smooth its ends.

b. Turn it in the flame of a fish-tail burner until it is soft, then

c. *Remove it from the flame* and bend its ends *upward.*



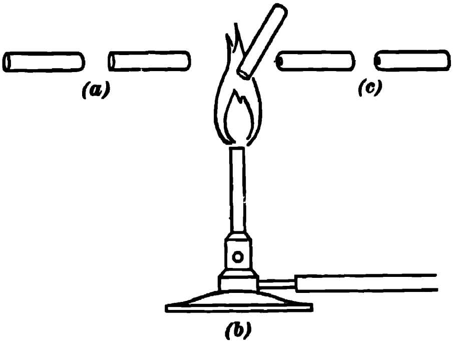
7. Glass T-Tube and Plug

a. Buy a T-tube made of No. 2 glass tubing.

b. To make a plug, cut a piece of No. 4 glass tubing 1½ inches long and smooth one end.

c. Turn the other end in a Bunsen flame above the green cone until it is entirely closed.

d. This plug fits the holes in the No. 8 rubber stoppers.



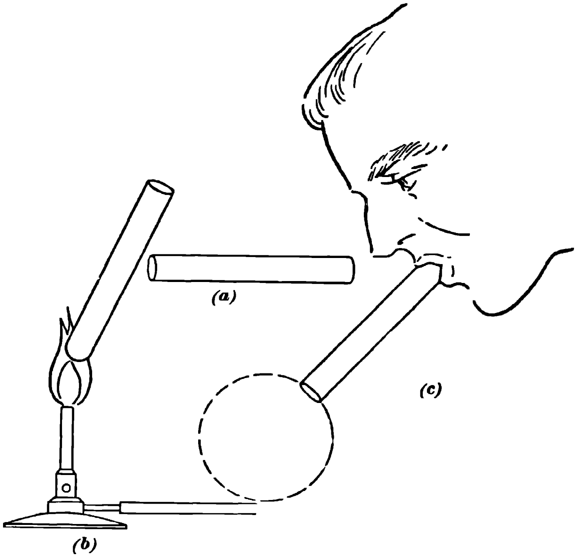
8. Glass Nozzles

a. Cut two pieces of No. 2 glass tubing 2 inches long and smooth one end of each.

b. Turn the other end of each in a Bunsen flame until it is *nearly* closed, and

c. You have two nozzles with small but strong jet ends.

Note. Examine all the glass pieces you have made. If you find an end that has contracted, cut it off ¼ inch and anneal it again. This does not apply of course to the small end of the nozzles or the closed end of the plug.



9. Large Glass Tube

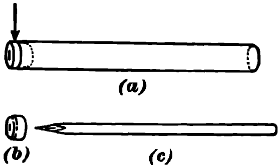
a. Cut a piece of No. 10 glass tubing 6½ inches long and smooth its ends. No. 10 tubing is ⅝ inch inside diameter.

b. If your laboratory has no No. 10 tubing, find a test tube 6 inches by ⅝ inside, and heat the closed end very hot.

c. Blow very hard into the test tube to make a large thin glass balloon.

Break away the thin glass and smooth the rough edge in the flame. The resulting large glass tube is only about 5½ inches long but it will serve.

d. You can buy the glass cylinder of a battery hydrometer for 5 cents at a ten-cent store. These are excellent.



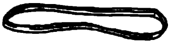
10. The Plunger

a. Put a No. 1 rubber stopper into one end of the large glass tube but do not press it in. Cut it off about ¼ inch beyond the end of the glass tube.

b. Bevel the cut-off end with a pair of scissors.

c. Insert the pointed end of a lead pencil into the hole at the small end of the stopper and twist it in to enlarge the stopper until it fits the large glass tube air-tight.

Note. If the rubber stopper is of just the right size, do not cut or trim it, of course.


(a)

(b)

(c)

(d)

(e)

11. Miscellaneous

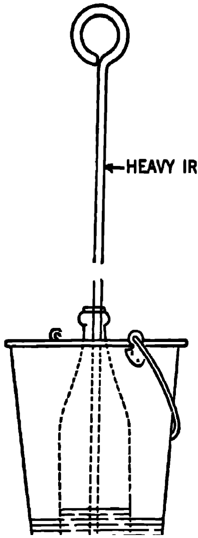
a. *Rubber bands.* It is important that you buy *long thin* rubber bands. Buy those 3½ inches long and $\frac{1}{16}$ inch or less in diameter.

b. *Faucet connector.* Buy this for 5 cents at a ten-cent store.

c. *Large balloons.* Buy at least two at 5 cents each.

d. *Medium balloons.* Buy at least two at two for 5 cents.

e. *Small balloons.* Buy five at 1 cent each.



12. Another Way to Cut the Bottom From a Bottle

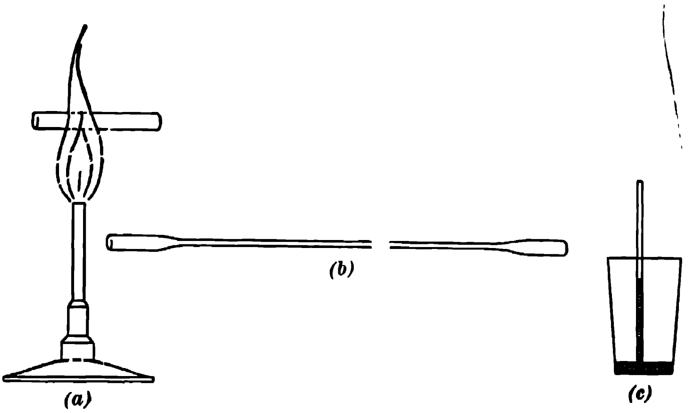
Fill the bottle with water to the point at which you wish it to break.

Stand it in a pail of water of the same depth.

Heat one end of a thick iron poker red hot *for a length of 8 inches* or more.

Place it in the water in the bottle and the bottom will crack off.

Smooth the rough edges with a file.

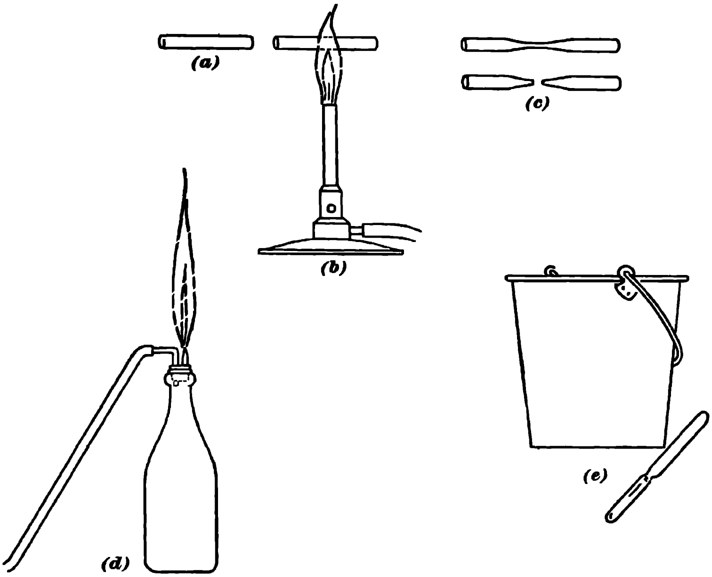


13. A Capillary Tube

a. Cut a piece of No. 2 glass tubing 5 inches long, and heat it in a Bunsen flame until it is quite soft.

b. Remove it from the flame and stretch it two feet or more. Break the narrow part into capillary tubes of about one foot length.

c. Place one end of one in a tablespoonful of ink in a tumbler. The ink will rise to a surprising height in the capillary tube.



14. A Sound-Wave Detector

a. Cut a piece of No. 2 glass tubing 5 inches long, and smooth its ends. Let it cool.

b. Turn it in a Bunsen flame above the green cone until it is soft.

c. Remove it from the flame, stretch it about two inches, and after it has cooled break the stretched part. You then have two pointed nozzles.

d. Arrange the equipment, turn on the gas and get a flame, 10 inches or more high, which is just about to flare. Use a nozzle with a *rough uneven mouth.* This is important.

e. Strike a tin pail with the blade of a knife to make a sharp sound and the tall flame will "duck" when the sound wave passes through it.

Where to Buy It

IN THE UNITED STATES

EXCELLENT RUBBER STOPPERS

R. W. Rhoades Metaline Co., Inc., Long Island City, N. Y.

RUBBER STOPPERS, RUBBER TUBING, GLASS TUBING, BUNSEN BURNER, AND FISH TAIL

Biological Supply Co., 1176 Mt. Hope Avenue, Rochester, N. Y.
Cambos Co. Scientific Co., 37 Antwerp St., Boston, Mass.
Central Scientific Co., 1700 Irving Park Blvd., Chicago, Ill.
Chicago Apparatus Co., 1735 N. Ashland Ave., Chicago, Ill.
A. Daigger and Co., 159 W. Kinzie St., Chicago, Ill.
Eimer and Amend, 633 Greenwich St., New York, N. Y.
Howe and French, Inc., 99-101 Broad St., Boston, Mass.
New York Laboratory Supply Co., 76 Varick St., New York, N. Y.
W. M. Welch Manufacturing Co., 1515 Sedgwick St., Chicago, Ill.
Wilkens-Anderson Co., 4223 W. Lake St., Chicago, Ill.
Will Corporation, Rochester, N. Y.

IN CANADA

Cave & Co., Limited, 567 Hornby St., Vancouver, B. C.
Canadian Laboratory Supplies, Limited, 32 Greenville St., Toronto 5.
Casgrain & Charbonneau, Limited, 445 St. Lawrence Blvd., Montreal.
Central Scientific Co., 146 Kendal Ave., Toronto 4.
Fisher Scientific Co., Limited, 904 St. James St., Montreal.

IN ENGLAND

Baird & Tatlock, Ltd., 14-17 Cross Ct., London E.C.1.
Gallenkamp & Co., Ltd., 17-29 Sun St., London E.C.2.

Note. In many parts of the country the diameter of the mouth of milk bottles has been reduced from $1\frac{11}{16}$ inches to $1\frac{7}{16}$ inches and to $1\frac{5}{16}$ inches. If the mouth of your milk bottles is $1\frac{7}{16}$ inches or $1\frac{5}{16}$ inches, order No. 6 rubber stoppers instead of No. 8 stoppers, *b*, page 215.

Explanations

BASEBALL CURVES AND THE LIKE

1—Bernoulli's principle is: A rapid stream of gas or liquid is surrounded by a low-pressure area and the more rapid the stream the lower is the pressure.

The ball above is moving through air *to the right.* We can, however, think of the ball as stationary with air streams moving around it *to the left.*

If the ball is revolving as shown, its upper surface retards the top air stream and its lower surface accelerates the bottom air stream.

The faster air stream and lower pressure are below, by Bernoulli's principle. Hence the atmosphere forces the ball downward in a "drop."

Revolving tennis and golf balls curve, for the same reason.

2—A revolving ball always curves in the direction in which its front is revolving. That is, "it follows its front" in curving, for the reason given in Explanation 1.

The ping-pong ball rolls along the *right* inner side of the mailing tube when you move the tube rapidly from *right* to left, hence its front is revolving toward the *right* when it leaves the tube. The ball then "follows its front" and curves to the *right.*

The ball rolls along the *left* inner side of the tube when you move the tube rapidly from *left* to right and its front is revolving toward the *left* when it leaves the tube. The ball then "follows its front" and curves to the *left.*

3—The ball, when shot forward, is started revolving by the drag of the wet tape. It "follows its front" in each case and curves in the direction its front is revolving.

4—Similar to Explanations 1, 2, and 3.

5—The tube "follows its front" and curves upward, but it is rotating so rapidly that it continues to "follow its front"; and it makes one complete loop, 360°, and sometimes two, 720°, before it reaches the ground.

6—You swing the ball in an arc of a circle, with your foot or feet as the center and your leg, body, and arm the radius. The greater the speed you give the ball in this circular arc the greater the speed it has when it leaves your hand.

7—It has been learned in thousands of tests that any body falling vertically downward gains velocity at the rate of 32.16 feet a second each second it falls, if the air resistance is small.

Similarly, it has been learned that any body thrown vertically upward *loses* velocity at the rate of 32.16 feet a second each second it rises, if the air resistance is small. The air resistance is small on compact smooth bodies at low speeds. For convenience we will use 32 instead of 32.16.

A ball thrown vertically upward loses velocity as it rises, and gains the same velocity in the opposite direction as it falls. It rises half the time and falls half the time.

If the ball was in the air for 5 seconds, it rose for $2\frac{1}{2}$ seconds and since it lost velocity at the rate of 32 feet a second each second it rose, it left your hand with a velocity of $32 \times 2\frac{1}{2} = 80$ feet a second.

8—The "center of percussion" is the scientific name for the "best spot" on a bat. If this center of percussion strikes the ball, the bat "moves as a whole" and there is no vibration.

If a point other than the center of percussion strikes the ball, the bat bends forward with its center of percussion ahead of its ends; the next instant the bat bends backward with its center of percussion behind its ends. This to-and-fro bending takes place very rapidly and it is this vibration which stings your hands.

9—If you can jump *upward* at a velocity of say 16 feet a second, you will rise $\frac{16}{32}$ or $\frac{1}{2}$ second because you will lose upward velocity at the rate of 32 feet a second each second you rise. You will also fall for $\frac{1}{2}$ second, hence you will be in the air $\frac{1}{2}+\frac{1}{2}$ or 1 second.

If your horizontal velocity is 25 feet a second, your broad jump will be 25 feet.

BUOYANCY OF LIQUIDS

10—*The law of Archimedes for liquids is:* A body placed in a liquid is buoyed up by a force equal to the weight of the liquid it displaces.

A cubic foot of fresh water weighs about 62.3 pounds; hence, by the law of Archimedes, each cubic foot of water you displace buoys you up with a force of 62.3 pounds.

If your volume is 2 cubic feet, the maximum buoyant force on your body in fresh water is $62.3 \times 2 = 124.6$ pounds.

Conversely, if you weigh 189.9 pounds in air, but only 3 pounds when completely submerged in fresh water, the buoyant force of the water on you is $189.9 - 3 = 186.9$ pounds and

your volume is $\frac{186.9}{62.3} = 3$ cubic feet.

11—*The law of Archimedes is:* The buoyant force exerted by a liquid is equal to the weight of the displaced liquid.

Human beings weigh *almost* the same as fresh water, volume for volume. Hence, when you are completely submerged (head and all) in fresh water, you displace about your own weight of water, and the buoyant force of this displaced water is about equal to your weight. As a result, when you are completely submerged in fresh water, you appear to have almost no weight at all.

But you need extra buoyancy to keep your head above water, and the cans shown here act as "life preservers" because they supply this extra buoyancy. If we assume that the cans, when completely submerged in fresh water, displace the volume indicated, the maximum buoyant force of the water on each depends on the fact that one gallon (U. S. measure) of fresh water weighs 8.33 pounds. Hence the maximum buoyant forces on the cans are: one gallon syrup can, $8.33 \times 1 = 8.33$ pounds; $2\frac{1}{2}$-gallon gasoline can, $8.33 \times 2\frac{1}{2} = 20.82$ pounds; 5-gallon paint can, $8.33 \times 5 = 41.65$ pounds.

In sea water the maximum buoyant force on these cans is slightly greater because one gallon (U. S. measure) of sea water weighs about 8.55 pounds.

12—Similar to Explanation 11. The buoyant force is equal to the weight of water displaced.

13—Similar to Explanations 11 and 12.

14—*d.* Water is nearly incompressible but air is easily compressed. The pressure you exert on the water with the palm of your right hand is transmitted by the water to the air in the pill bottle and compresses it. This decreases the volume of water displaced by the air and, by the law of Archimedes, it decreases the buoyant force on the bottle and air. The bottle and air then sink by gravity.

When you decrease the pressure on the water, the water decreases its pressure on the air; the air in the pill bottle expands and increases the volume of water displaced. This increases the buoyant force of the water on the bottle and air until it is great enough to lift them against the force of gravity.

15—See the law of Archimedes in Explanations 10 and 11. As stated in Explanation 14, water is nearly incompressible but air is easily compressed. Hence in *c* the pressure you exert on the cork is transmitted by the water to the air in the diver and compresses the air. This decreases the volume of water displaced by the diver and thereby decreases the buoyant force on the diver until it sinks by gravity.

d. When you lift the cork, you decrease the pressure on the water, the water decreases its pressure on the air, and the air in the diver expands. This increases the volume of water displaced and thereby increases the buoyant force of the water until it is great enough to lift the diver against the force of gravity.

16—See the law of Archimedes in Explanations 10 and 11.

a. The potato submarine sinks to the bottom because it displaces a weight of fresh water less than its own weight.

e. The potato submarine floats on the surface at such a depth that it displaces a weight of salt water equal to its own weight.

f. The potato submarine sinks until it displaces a weight of fresh and salt water equal to its own weight.

17—*b*. The baking soda and vinegar combine to produce a large volume of carbon-dioxide gas (CO_2).

Baking soda + vinegar = sodium acetate + carbon-dioxide + water

$NaHCO_3 + CH_3COOH = CH_3COONa + CO_2 + H_2O$

Much of the CO_2 gas is still dissolved in the liquid and the apple seeds help this gas to escape in the form of bubbles.

e. Gas bubbles cling to each seed and thereby increase the volume of water displaced until the buoyant force of this displaced water is great enough to lift the seed to the surface, against the force of gravity. At the surface gas bubbles escape and thereby decrease the volume of water displaced until the buoyant force of the displaced water is less than the weight of the seed, and the seed sinks to the bottom by the force of gravity.

18—*b*. The buoy sinks until the volume of water it displaces has a weight and a buoyant force equal to its own weight.

c. It does not sink so far in salt water as in fresh, because salt water is heavier volume for volume than fresh water.

d. It sinks to the bottom in kerosene because it cannot displace a weight of kerosene equal to its own weight, since kerosene is only $\frac{8}{10}$ as heavy as fresh water, volume for volume.

19—*a*. A gallon (U. S.) of water weighs 8.33 pounds. If then the pail holds 12 quarts or 3 gallons, it holds, when full to the top, $8.33 \times 3 = 24.99$ pounds of water.

b. If the pail has a volume of 12 quarts, or 3 gallons, and you sink it in water to its top rim, it displaces 3 gallons of water and the buoyant force of the water is $8.33 \times 3 = 24.99$ pounds. See the law of Archimedes in Explanation 10.

The downward force you must exert to sink the pail to its top rim is $8.33 \times 3 = 24.99$ pounds.

20—If the top surface of the rubber bag is 10″ x 7″, or 70 square inches, its area is $\frac{70}{144}$ square feet, since 1 square foot = 144 square inches.

The *density* of water is 62.3 pounds per cubic foot.

If the water surface is 6 feet above the top of the bag, the upward force on the top surface of the bag is as follows:

Force upward = area of the surface in square feet *times* the height of the water in feet *times* the density of the water in pounds per cubic foot.

Force upward $= \frac{70}{144} \times 6 \times 62.3 = 181.7$ pounds.

AIR PRESSURE

21—The atmosphere surrounding the earth is many miles deep. It is attracted by the earth and therefore it has weight. It exerts a pressure of 14.7 pounds per square inch on everything on the earth at sea level. For convenience in our thinking, let us call the pressure of the atmosphere at sea level, 15 pounds per square inch.

a. After the steam from the boiling water has driven the air out of the kerosene can, pure steam issues in bubbles. Each cracking sound is caused by the collapse of a bubble. The steam in the bubble cools very quickly and, condensing to water, leaves a vacuum in the bubble. The atmosphere then drives the sides of the bubble together so rapidly that they produce a cracking sound. It is much like the sound you produce when you clap your hands once.

b. When it is cooled by the cold water, the steam in the can condenses to water and leaves a partial vacuum in the can. Then the atmospheric pressure on the water in the bottle drives the water from the bottle, up the tube, and into the can.

Note. The cap of an oil can is, as a rule, not air-tight. You use the raw half-potato to make the top air-tight.

22—*c.* The steam drives nearly all the air out of the bottle.

d. The steam condenses to water, as it cools, and leaves a partial vacuum in the bottle.

e. The atmospheric pressure pushes the rubber down into the partial vacuum, and—

f. Bursts the rubber with a BANG.

23—*c.* The steam from the water boiling inside the can drives air out of the can, and when it cools and condenses to water it leaves a partial vacuum in the can. The end of a No. 2 can has an area of about 9 square inches. Since atmospheric pressure is 15 pounds per square inch, the force the atmosphere exerts on the end of the can is $9 \times 15 = 135$ pounds. This is the force you would have to exert to lift the can if the steam had produced a complete vacuum in the can. It is also the force your friend would have to exert to hold the sauce-pan down.

24—The pressure of the atmosphere on your body is 14.7 pounds on every square inch. This is the same pressure per square inch as that of a column of fresh water 34 feet tall. We can say then that the pressure of the atmosphere on your chest is equal to the pressure of 34 feet of water. We can say also that the pressure of the atmosphere on the water surface in the sauce-pan is equal to the pressure of 34 feet of water. If the height of the water column in the rubber tube and funnel is, say, 4 feet from the water surface in the sauce-pan to your chest, then the pressure on the part of your chest covered by the funnel top is only 34−4, or 30 feet of water. The atmospheric pressure per square inch on your chest *outside* the funnel is greater than the pressure of the atmosphere per square inch on your chest *inside* the funnel by an amount equal to the pressure per square inch of 4 feet of water. This greater outside pressure pushes your chest into the funnel. This gives you the feeling called *suction*.

25—The air in each balloon is under pressure. Hence it is compressed and it weighs more than an equal volume of outside air.

Each balloon is buoyed up by a force equal to the weight of the outside air it displaces.

The weight hanging on each safety pin then is: The weight of the balloon and cord, plus the weight of the air compressed in the balloon, minus the weight of the outside air displaced by the balloon.

When one balloon is emptied, the weight of the small volume of air left in it is supported by the buoyant force of the outside air it displaces. Hence the only weight on the safety pin is that of the balloon and cord, and this side is raised by the weight of the compressed air in the other balloon plus the weight of this balloon and its cord minus the weight of the outside air displaced.

COMPRESSED AIR

26—*b*. The egg, when pushed down, compresses the air in the bottle and thereby increases its pressure outward.

c. This increased outward air pressure shoves the egg out again.

27—*a*. When the lower end of the funnel is closed by your thumb, and you blow down hard, your air stream does two things: First, it increases the downward air pressure on the top face of the dime. Second, it drives air down into the closed space below the dime and increases the amount of air in this closed space. This increases the upward air pressure on the under face of the dime and it is this upward air pressure that lifts the dime.

b. When your thumb does *not* close the lower end of the funnel, your air stream increases the downward air pressure on the top face of the dime, but it cannot increase the upward air pressure on the under face. The dime therefore remains stationary.

28—*a*, *b*. Similar to Explanation 27—*a*.

29—*b*. A small part of the air you blow into the mouth of the bottle strikes the paper ball and tends to blow it into the bottle. But a far larger part of the air passes the ball and increases the amount of air in the bottle. This increases the outward pressure of the air in the bottle and it is this outward air pressure that drives the paper ball out.

30—Pressure exerted on a confined gas is transmitted by the gas *equally* and *undiminished* in all directions to the inner sides of the containing vessel.

This is Pascal's law for gases.

If, for example, you blow into the bag with an air pressure of 2 pounds per square inch, and if the top surface of the hot water bag is 10" x 7" or 70 square inches, your total lift will be $70 \times 2 = 140$ pounds.

31—The balloon rubber is held so firmly against the inner side of the cup and tumbler by air pressure that it has an excellent grip.

32—*c*. The steam drives air out of the large bottle.

d. The steam condenses to water and leaves a partial vacuum in the large bottle. Then the air in the small bottle expands into this partial vacuum and blows up the balloon.

33—The air in the balloon expands and stretches the balloon down into the near vacuum left when the steam condenses to water. The atmosphere pressing on the outside of the balloon tends to force it into the tumblers.

BUOYANCY OF GASES

34—The acid dissolves the zinc and liberates hydrogen. The chemical equation is:

Zinc+hydrochloric acid=zinc chloride+hydrogen

$Zn + 2\ HCl = ZnCl_2 + H_2$

Hydrogen weighs only about one-fourteenth as much as air, volume for volume. The balloon rises when the upward force acting on it is greater than the downward force. The upward force is equal to the weight of the air displaced by the balloon. The downward force is equal to the weight of the balloon rubber and cord, plus the weight of the hydrogen in the balloon. See the law of Archimedes for gases in Explanation 33.

35—The household lye is sodium hydroxide. It dissolves the aluminum and liberates hydrogen. The chemical equation is:

Aluminum+sodium hydrate+water =Sodium aliminate+hydrogen

$2\ Al + 2\ NaOH + 2\ H_2O = 2\ NaAlO_2 + 3\ H_2$

The balloon rises for the reason given in Explanation 34.

36—*a*. The hot water warms the carbon-tetrachloride liquid and turns it into a gas quickly.

b. Carbon-tetrachloride is CCl_4. The atomic weight of carbon is 12 and that of chlorine is 35.5. Hence the molecular weight of CCl_4 is $12+(4\times35.5)=12+142=154$.

Air is not a compound, but if it were its molecular weight would be 28.8. Hence carbon-tetrachloride *gas* is $\frac{154}{28.8}=5.3$ times as heavy as air, volume for volume.

The law of Archimedes for gases is: Any body placed in a gas is buoyed up by a force equal to the weight of the gas it displaces. The air bubble floats when the weight of the CCl_4 gas it displaces is equal to its own weight.

37—The paper bags are filled with air and one of them rises because it is buoyed up by a force equal to the weight of the CCl_4 gas it displaces.

38—The CCl_4 gas does not support combustion and it pours because it is 5.3 times as heavy as air, volume for volume.

39—The bag filled with CCl_4 gas sinks because CCl_4 gas is 5.3 times as heavy as air, volume for volume. See Explanation 36.

40—The baking soda and vinegar combine and liberate carbon-dioxide gas. The chemical equation is:

Baking soda + vinegar = sodium acetate + carbon-dioxide + water

$$NaHCO_3 + CH_3COOH = CH_3COONa + CO_2 + H_2O$$

The atomic weight of carbon is 12, that of oxygen 16. Hence the molecular weight of carbon-dioxide gas is $12+2\times16=44$, and carbon dioxide gas is $\frac{44}{28.8}=1.5$ times as heavy as air, volume for volume. See Explanation 36.

Carbon-dioxide gas does not support combustion. It pours because it is heavier than air, volume for volume.

AIR STREAMS

41—*a*, *b*. Bernoulli's theorem is: A rapid stream of gas or liquid produces low pressure in the space around it. The more rapid the stream the lower the pressure.

Your rapid air stream produces low pressure between the paper halves and the atmosphere on the outer side of the halves pushes them together.

42—Similar to Explanation 41.

43—*a.* Your rapid air stream produces low pressure over the paper. The atmosphere below the paper pieces then lifts them into this low pressure area and into the air stream which carries them away.

b. Your rapid air stream produces low pressure at the mouth of the bottle. The air in the bottle expands and pushes the paper ball into this low pressure area. The momentum of the paper ball shoots it into the air stream, by which it is carried away.

44—Your rapid air stream produces low pressure above the dime. The atmospheric pressure on the under surface of the dime then lifts it into this low pressure area. The momentum of the dime shoots it up into the air stream and the air stream carries it toward the plate.

45—Your air stream divides and each half-stream produces low pressure between itself and the bulb (see Bernoulli's theorem). Each half-stream is held against the bulb by the atmospheric pressure on its outer side. The half-streams pass around the bulb and unite on the far side where they blow out the flame.

46—*a.* Your rapid air stream divides when it strikes the can and each half produces low pressure between itself and the side of the can (Bernoulli's theorem). Each half-stream is held against its side of the can by the atmospheric pressure on its outer side. The halves unite on the far side of the can and blow out the flame.

b. Similar to *a*, except that the two air streams cannot unite on the far side of the first can. Each half flows around its side of the second can and produces low pressure between itself and its side of the can. Each half is held against its side of the can by the atmospheric pressure on its outer side. The half air-streams unite on the far side of the second can and blow out the flame.

c. Similar to *a* and *b*, with one more can.

47—*a, b.* Part of your air stream shoots straight ahead, but that part which touches the side of the egg produces low pressure between itself and the side of the egg (Bernoulli's theorem). It is held against the side of the egg by the atmospheric pressure on its outer side. Hence it curves around the egg and blows out the flame.

c. Similar to Explanation 45.

d. Similar to Explanation 41.

48—*a, b.* The balloon is surrounded by rapidly moving air. Hence it is surrounded by a low-pressure area, by Bernoulli's theorem. The balloon remains in the air stream because, if it moves to the edge, the greater atmospheric pressure on its outer side shoves it back into the stream against the lower pressure exerted against its inner side by the rapid air stream.

The balloon is *supported* by the upward force of the air stream.

49—*a*, *b*. Similar to Explanation 48.

50—Your rapid air stream spreads out into a sheet which clings to the inner side of the funnel, because it produces low pressure between itself and the funnel and the atmosphere keeps it pressed against the inner side of the funnel. Your air stream comes out of the large end of the funnel in the shape of a hollow cone with a partial vacuum at its *middle*. The atmosphere pushes air into this partial vacuum and blows the flame *toward* you. The air stream flows outward from the *rim* of the funnel and blows the flame *away from* you.

51—*a*. Your rapid air stream produces low pressure between the side of the ball and the inside of the funnel (Bernoulli's theorem) and the atmosphere pushes the ball down.

b. The water stream produces low pressure between the ball and the inside of the funnel (Bernoulli's theorem) and the atmosphere holds the ball up.

WATER STREAMS

52—*b*. The rapid stream of water produces low pressure between the balloon and the rim of the funnel. Then the upward force of the atmosphere on the under side of the balloon supports the balloon against the downward force of the water stream on its top side, and against the pull of gravity on the balloon.

53—The vertical water stream divides and flows down on all sides of the ball. It produces low pressure between itself and all sides of the ball (Bernoulli's theorem) and the greater atmospheric pressure on its outer side makes it grip the ball.

The vertical stream takes the ball with it when it moves, for this reason: When the stream shifts to one side of the ball it produces the lowest pressure on that side because its velocity is greatest there. Then the greater atmospheric pressure on the opposite side pushes the ball back into the stream.

54—The rapid water stream produces a low-pressure area between itself and the side of the balloon it touches. The atmosphere behind the balloon and behind the stream holds them together. You feel a fairly strong pull because the balloon is shoved *into* the stream and part of the water falls on its upper side. Your upward pull must balance the downward force of this upper water and also the weight of the water which clings to the under side of the balloon.

55—There is an upward flow of water as well as a downward flow, because the water which enters the tumbler must come out again; and it is the upward flow which lifts the egg.

It is the Bernoulli effect of the upward and downward flows, however, which keeps the egg centered in the middle of the flows. If the egg starts to move out of the flows, the greater velocity and lower pressure are on its inner side. Then the greater atmospheric pressure on its outer side shoves it back into the flows.

56—*Bernoulli's theorem is:* The pressure is low in a rapid stream of liquid or gas, and the more rapid the stream the lower the pressure. The water stream clings to the sides of the apples it falls on. It therefore flows down between the apples and produces low pressure between them. Then the greater atmospheric pressure on the outer sides of the apples (exerted through the water) presses them together.

LIQUID SURFACES

57—*a.* The attraction between the water and the metal holds them together while the water flows down the rod.

b. The attraction between the water and the glass holds them together while the water flows along the under side of the glass.

It is an optical illusion when you appear to see the water flowing from the inside. You are accustomed to seeing water flow from the *inside* of a tumbler, not from the outside. Hence you see it as flowing from the inside.

58—*b.* The water surfaces on the two wet paper strips unite and pull the strips together *instantly* because the water surfaces contract *instantly* to the smallest possible area.

59—Lycopodium powder does not absorb water readily. It forms a film on your thumb and fingers which prevents the water from reaching them.

60—*a.* The surface of any liquid tends to contract to the smallest possible area. This contracting force or tension is called the *surface tension* of the liquid.

A sphere is the volume which has the smallest possible area of surface for a given volume. The lycopodium powder forms an outer layer on each drop which prevents the water from touching the saucer. The surface tension of the water then pulls the drop into a perfect sphere.

If the water does touch the saucer the sphere is flattened at once, because the *adhesion* between the saucer and water is greater than the *cohesion* of the water.

b. The surface tension of the water pulls small volumes of water into perfect spheres.

61—*c*. The *surface tension,* or pull of the surface, of any liquid shapes it into perfect spheres when the liquid is free from the force of gravity. For a short distance between the water and alcohol the mixture of the two has the same weight as salad oil, volume for volume. Here the salad oil is free from gravity and its surface tension shapes it into perfect spheres.

62—*c*. The surface of any liquid tries at all times to contract to the smallest possible area. This contracting force is called its *surface tension* The Duco cement weakens the water surface at the stern of the boat. Then the unweakened water surface at the bow contracts and pulls the boat away from the weakened area.

63—*c*. Similar to Explanation 62—*c*.

64—The surface of a liquid acts like a fairly strong film. The surface of cold water is quite strong. The surface of hot soapy water is about one-half as strong. The surfaces of kerosene and carbon tetrachloride are respectively about one-third and one-fourth as strong as the surface of pure cold water.

The razor blades float on the strong surfaces and break through the weak surfaces.

65—Paper should float on any liquid because it is lighter volume for volume than any liquid.

It sinks in a liquid when the liquid runs up into its pores and pulls it down.

Its pores are very small and the surface of the liquid *must bend into a very small pointed angle* in order to enter them.

The paper sinks slowly in cold water because the surface of cold water is strong and does not bend easily. It sinks rapidly in kerosene and carbon tetrachloride because their surfaces are weak and bend easily.

Note. Every good cleansing liquid has a weak surface which bends readily into pores and into the narrow space between dirt and the surface to be cleaned.

66—Dip the double pen in and out of ink and you will see the outer sides of the two pens wet with ink. You will also see a fairly long column of ink between the inner sides of the pens. This column is held up by its strong upper surface, which forms a bridge between the inner sides and lifts the column. It is this inner column of ink which gives the fountain pen effect, because it enables you to write a long time between dips.

67—*a*. The water penetrates into the pores of the paper and rises in the pores because the *adhesion* between the paper molecules, just above the water surface, and the water molecules in the surface, is greater than the *cohesion* between the water molecules. It stops rising when the cohesion plus the weight of the water column raised equals the adhesion.

This is called capillarity.

b. Similar to *a*.

c The water rises in the cloth as in *b*, and runs down into the outer half. The water in the cloth then becomes in effect a siphon.

68—*a*. The ink rises in the sugar for the reason given in 67—*a*.

c. The salt forms crystals around the edge of the surface. Then salt water rises in these crystals by capillarity and forms more crystals just above. This continues and salt crystals move up the inside of the tumbler to the top and frequently down the outside.

69—*b*. The attraction between two molecules *in motion in the same direction* seems to be greater than the attraction between the same molecules at rest and the same distance apart (the writer's theory).

When the ink drop falls into water, its center moves downward and this motion starts the circumference *revolving*. The moving molecules cling together, but centrifugal force gradually drives them apart. This causes the ring to *thicken*. The flattening of the falling drop also causes each cross section of the ring to move outward. This motion causes the ring to expand..

c. Similar to *a*.

70—*b*. The soap film contracts to the smallest possible area as you stretch the wire spiral and takes the shape of a spiral ramp.

71—When you separate the large bubble from the funnel, notice that the bubble is *pear-shaped* just before it leaves the funnel. The earth (large bubble) is formed from the body of the pear, and the moon (very small bubble) from the neck of the pear.

At the time the molten earth-mass was thrown off by the whirling molten sun, it was probably pear-shaped. Then the earth was formed from the body of the pear, and the moon from the neck of the pear.

72—The surface of the soap bubble contracts and drives the gas out of the funnel.

73—Water enters the dry wood cells in the bend of a match and *swells* the cells. This swelling tends to straighten the match and makes its ends move farther apart. The ends of the five matches meet and make a five-pointed star.

74—Water enters the paper cells in each bend it touches, and swells them. This swelling straightens the bends and makes the serpent stretch.

CENTRIFUGAL FORCE

75—If a body is moving in a circle, the force with which its weight pulls away from the center of the circle is called the *centrifugal force* of the weight. The greater the weight and the greater its speed, the greater is its centrifugal force.

The equal and opposite force which must be exerted toward the center to keep the weight in its circular path is called the *centripetal force*.

a. The hammer exerts *centrifugal force* and you must exert an equal and opposite *centripetal force* to keep it in a circular path.

b. Similar to *a*.

76—The centrifugal force of the revolving water moves it away from the center of the umbrella.

77—Similar to Explanations 1, 2, 3, 4, and 5.

78—*a* The centrifugal force produced by the weight of the spikes moving in a circle tends to move these weights as far as possible away from the center of the circle. This condition is fulfilled when the circle is horizontal.

b. The centrifugal force produced by the weight of the single spike moving in a circle tends to move this weight as far as possible away from the center of the circle. It is this centrifugal force which lifts the spike from a vertical to a horizontal position.

79—In each case the centrifugal force lifts the body from a vertical to a horizontal position, because in this horizontal position the greatest amount of the weight of the body is farthest from the center or axis of revolution and the total centrifugal force is greatest.

80—The centrifugal force produced by any weight revolving in a circle pulls that weight as far as possible away from the center of the circle.

a. The centrifugal force of the water moving in a circle moves the the water away from the center, up the inside, and over the top.

b. The centrifugal force of the water moving in a circle moves the water as far as possible from the center or axis of revolution—that is, to the equator of the bowl.

81—Each particle of water moves toward the outlet along a downward spiral path. Each is acted on by two forces: Gravity, the attraction of the earth, pulls it downward, and centrifugal force tends to move it farther from the axis of revolution. As a result, each particle moves along a downward spiral path.

PENDULUMS

82—The baseball shoves air aside during each swing and thereby loses the energy it gives to the air. As a result, each swing is a little shorter than the preceding swing.

83—*Newton's third law of motion states:* To every action there is an equal and opposite reaction. The baseball must be given a slight sidewise motion to make it miss the pencil on the forward swing. This "action" will produce an equal and opposite "reaction" which will make the baseball miss the pencil by an equal distance on the opposite side during the backward swing.

84—The time in each case is proportional to the square root of the length of the pendulum. But the lengths are the same. Hence the times are the same.

85—Explained in the text.

86—The pendulum has two points of support: the two tacks. Hence it is, in effect, two pendulums, and its motion is a combination of the motion of the two pendulums. The movement of the cord moves the soda straws and the straws cause the pin to trace curves. The pendulum makes smaller curves as it slows down gradually, and in doing so it draws beautiful designs.

87—The swinging pendulum gives the second pendulum a slight push, through the light stick, each time it swings and in doing so gives up some of its energy. These pushes set the second pendulum swinging because each comes at exactly the right time and in the right direction. This continues until the first pendulum comes to rest because it has given all of its energy to the other pendulum. The second pendulum is now in full swing and it begins to set the first pendulum swinging again, and so on.

Note. This works best when the pendulums are of exactly the same length and hence have exactly equal times of swing, or periods.

HEAT ENGINES

88—The steam issuing from the nozzle with high velocity strikes the blades and revolves the turbine rapidly.

89—Similar to Explanation 88.

90—*d.* Each steam jet shoots in one direction with a certain force and drives its side of the can in the opposite direction with the same force.

91—The expansive force of the steam lifts the saucer and the balloon. Each lift is a power stroke.

92—The gasoline liquid turns to a gas and the gas mixes with the air in the can. The mixture burns very rapidly and produces a great deal of heat which expands the mixture very rapidly. This rapid expansion is the explosion which lifts the can cover. This action illustrates the power strokes of a gasoline engine.

93—*b*. Air is heavier volume for volume than the fuel gas. It enters the lower hole and lifts the lighter fuel gas upward and out through the upper hole. Here the gas burns in air which enters the flame from the sides.

c. By the time the flame is low, the remaining gas and the air in the can have mixed by diffusion. When the flame ducks down into the hole, this mixture of gas and air burns very rapidly, and produces heat very rapidly which expands the gases in the can very rapidly. That is, the mixture "explodes." This illustrates the power strokes of a gas engine.

94—*d*. The fine cornstarch powder burns very rapidly in the air in the can when it is lighted by the candle. It produces an explosion for the reasons given in Explanations 92 and 93.

95—*b*. Similar to Explanation 93

EXPERIENCES WITH HEAT

96—*b*. Fuel gases, oils, and wood consist of compounds of carbon and hydrogen. When they burn, the carbon in them unites with oxygen to form carbon-dioxide gas (CO_2) which remains a gas. But the hydrogen combines with oxygen to form water (H_2O) in the form of steam. This steam condenses to liquid water when it strikes the cold sauce-pan.

97—Water boils at 212° F. and it keeps the paper at near this temperature. The paper does not burn because its kindling temperature is much above 212° F.

98—All gases expand when heated and contract when cooled.

99—The kinetic theory of heat is that *heat is the energy of motion of the molecules of a substance.* It is believed that the molecules of all substances are in constant motion and that when a substance is heated its molecules move more rapidly and have greater energy. Conversely, when a substance is cooled its molecules move less rapidly and have less energy.

Why do substances expand when heated and contract when cooled? A substance expands when heated because its molecules move more rapidly, strike one another harder, and drive one another farther apart against their cohesion. A substance contracts when cooled because its molecules move less rapidly and strike one another with less force. Then their force of cohesion draws them closer together.

The tumbler is heated by the hot water and it in turn warms the cold air which fills it after the hot water is emptied out.

The tumbler is raised slightly above the glass plate by the heat expansion of the cold air and it is then pulled by gravity down the slide. Its path is lubricated by the hot water which drips down its inner side.

100—*h*. All metals expand when heated and contract when cooled.

101—The writer is not sure of the explanation of this phenomenon. Apparently the salt prevents the linen from being burned completely but permits it to be turned into a thread of carbon. Each small weight seems to be supported by a thread composed of carbon and fused salt.

102—Water turns to steam when it boils, the steam leaves the kettle, and that part of it which is cooled by the cold water turns back to water.

Since the solid impurities in the water do not turn to a gas they remain in the kettle.

103—*a*. The steam fills the bottle and drives out the air.

b. The stopper keeps air out of the bottle.

c. The cold water condenses much of the steam in the bottle. There is then less steam above the water and therefore less pressure on the water. Under this lowered pressure the water boils and produces more steam. The cold water condenses this steam and lowers the pressure still more. The water boils at a lower temperature at this lower pressure, and so on.

104—*a*. Part of the energy you expend in rubbing the tack on the floor or carpet is turned into heat and this heat warms the tack and also the floor or carpet.

b. Each rosin particle burns rapidly with a long flame and this long flame looks like lightning.

105—*a*. The temperature at which ice melts is by definition 32° F.

b. Salts makes ice melt more rapidly than it would if there were no salt present and the heat required to melt the ice comes partly from the surroundings and partly from the mixture itself. When the mixture loses heat it cools below the temperature of the melting ice.

c. Water evaporating from the cloth takes heat from the surroundings and from the bulb to which it is attached and it thereby cools the thermometer. The drier the air the more rapid is the evaporation and the greater the cooling, and vice versa.

106—*b*. Salt makes the ice melt fast, and part of the heat needed to do this fast melting comes out of the ice cube itself. This lowers the temperature of the ice cube and the fresh water in the string loop freezes it to the top of the cube at this lowered temperature.

107—The reason water at 39.2° F. (4° C.) is heavier than water at higher and lower temperatures is as follows: Water contracts and becomes heavier and heavier volume for volume as it is cooled to 39.2° F. But it expands and becomes lighter and lighter as it is cooled below 39.2° F. because *it begins to turn into ice at 39.2° F, not at 32° F.* The ice crystals are so small at first that they are invisible, but they are lighter than water, and they make the mixture of ice crystals and of water below 39.2° F. lighter than water at 39.2° F. The crystals grow larger and more numerous as the water is cooled still further and make the mixture still lighter. The ice crystals float slowly up to the surface and at 32° F. combine into a solid sheet of ice on the surface. Sheet ice, being a poor conductor of heat, slows up the rate of cooling of the water under it. Hence water at the bottom of a deep lake remains at 39.2° F. all winter, and the fish and aquatic plants are not frozen.

108—*a*. When water and milk (which is mostly water) freeze, they expand with enormous force and break the bottles. Kerosene thickens as it cools but does not freeze. Strong salt water freezes only at very low temperatures.

b. Ice contracts when it melts, and the great pressure of the wire helps the ice just below the wire to contract and melt at temperatures below 32° F. Part of the heat to do this melting comes from the ice and water just under the wire and thereby lowers its temperature. The water which forms under pressure beneath the wire is therefore below 32° F. This water turns solid as soon as it flows above the wire and is no longer under pressure. Hence the wire cuts down through the ice but leaves the block of ice as solid as it was at the start. This is called *regelation.*

109—Dry ice is solid carbon dioxide (CO_2). It is at a temperature of −110° F. It is called dry because it changes directly from a solid to a gas without going through the liquid state. That is, it "sublimes."

A piece of water ice also sublimes if it is left outdoors in winter when the temperature is below 32° F. That is, it eveporates directly from a solid to a gas without going through the liquid state.

a. Heat from the water changes the carbon-dioxide solid into carbon-dioxide gas, which is invisible. The CO_2 gas is so very cold that it condenses water vapor into a visible cloud, that is, into millions of minute drops of water.

b. The cloud is mixed with CO_2 gas, which is heavier than air. See Experience 40. A bubble filled with air floats when it displaces a weight of this mixture equal to its own weight. *The law of Archimedes for gases is·* Any body placed in a gas is buoyed up by a force equal to the weight of gas it displaces.

c. Carbon-dioxide gas does not support combustion.

d. Carbon-dioxide gas pours because it is heavier than air, volume for volume. Also cold air is heavier than warm air, volume for volume.

110—*a.* The part of the knife that touches the dry ice at −110° F. contracts rapidly as it cools. It also expands rapidly when it no longer touches the dry ice. This contraction and expansion sets up irregular vibrations which cause the groaning sounds.

b. The rubber loses some of its elsaticity when it is cooled.

c. Heat from the thermometer bulb moves through air and CO_2 gas slowly because gases are poor conductors of heat.

d. Kerosene is a slightly better conductor of heat than is a gas.

111—It is interesting that thread, string, or rope made of materials of *vegetable origin,* such as linen, cotton, and hemp, *shrink* as they *absorb moisture* from the air and *stretch* when they dry out again. It is interesting also that materials of *animal origin,* as wool or silk, act in the opposite manner. The writer does not know why.

112—Directions

113—All liquids are poor conductors of heat

WATER PRESSURE

114—The long water column in the tank and long rubber tube exerts pressure on the air in the lower bottle, compresses it, and drives it up through the short rubber tube into the top of the upper bottle.

Here the pressure of the compressed air lifts the shorter column of water measured from the water surface in the upper bottle to the top of the water jet.

It is not perpetual motion because as soon as the lower bottle and short rubber tube are filled with water, the jet will no longer rise above the water level in the tank.

115—The pressure of the water in the tank and tubes produces the fountain.

116—The pressure of the water in the tank and tubes compresses the air in the bottle after the water level in the bottle reaches the lower end of the lower union. The pressure of the compressed air then lifts the water and produces the fountain.

117—The pressure of the water at each nozzle is equal to that of a column of water measured from the middle of the outlet of the nozzle to the water surface in the bottomless bottle. Hence the pressure at the lower nozzle is greater than that at the upper.

118—Method.

119—The top surface of the hot-water bag is about 10 inches long and 7 inches wide. It therefore has an area of 10×7=70 square inches.

If the water column in the tank and tubes exerts a pressure of, say, 2 pounds per square inch on the water at the mouth of the bag, this pressure, by Pascal's law, is transmitted equally and undiminished by the water; and the pressure on the inside surface of the bag is 2 pounds on each square inch.

The total lift on the upper surface is then 70×2=140 pounds.

This force will lift many pints of water.

120—If the pressure of the water from the faucet is, say, 20 pounds per square inch at the mouth of the bag, the pressure on each square inch of the inside surface of the bag is 20 pounds by Pascal's law.

If the area of the top of the bag is 70 square inches as in Experience 119, the total lift is 70×20=1,400 pounds. It will lift you and many others.

121—The force of the water drives the wheel.

122—*Newton's third law of motion states:* To every action there is an equal and opposite reaction.

The water leaves an elbow in one direction with a certain force. This is the "action" and, by Newton's third law, it exerts an equal force in the opposite direction on the elbow. It is this latter force, the "reaction," which turns the turbine.

123—Similar to Explanation 122.

124—The *momentum* of any body is defined as its quantity of motion. It is equal to the product of its weight and velocity.

a. The water in the horizontal tube has momentum because it has weight and velocity.

b. When you pinch the union you destroy the horizontal velocity but you do not destroy the momentum. It is used up in giving the small weight of water in the vertical tube a greater vertical velocity which carries it above the level of the water in the bottomless bottle.

125—*a, c.* The hydrostatic paradox is: the pressure of a *stationary* column of water at a given point is independent of the volume of water in the column and depends only on the height of the water above the given point.

b, d. The hydrostatic paradox does not apply when the water is in motion.

Here the *head* or pressure which is producing the motion is that of the column measured vertically from the outlet to the water level in the bottomless bottle.

Part of this pressure is producing motion and the remainder is producing static pressure in the vertical tube. The greater the velocity produced the less is the static pressure.

e. The head here is more than doubled and this increases the velocity to such an extent that the static pressure at a point near the bottle is less than zero or negative. Negative pressure is called "suction."

ATMOSPHERIC PRESSURE

The atmosphere of the earth is attracted by the earth and hence it has weight. It exerts a pressure of 14.7 pounds, nearly 15 pounds, on each square inch of everything on the earth's surface at sea level. It exerts this pressure equally in all directions—upward, downward, and sidewise—at a given level.

A pressure of 14.7 pounds per square inch is equal to that of a column of water 34 feet deep. This means that if the atmosphere of the earth were removed and replaced by an ocean of water 34 feet deep, the pressure 34 feet under water would be the same as that exerted by the atmosphere, namely 14.7 pounds per square inch.

The atmosphere can support a column of water 34 feet high at sea level if there is a vacuum, or zero pressure, at the top of the column.

For convenience we will call the pressure of the atmosphere at sea level 15 pounds per square inch, instead of 14.7.

126—*b.* The steam drives the air out of the milk bottle.

c. When the steam cools and condenses to water it leaves nearly a vacuum in the bottle. The atmosphere pressing down on the water surface in the pail can lift water 34 feet high and it lifts the water 6 or 8 feet up into the bottle easily.

127—The steam drives nearly all the air out of the milk bottle and leaves a fairly high vacuum when it condenses to water.

The air in the soda bottle then expands into the low-pressure area in the milk bottle and this decreases the air pressure in the soda bottle. The atmospheric pressure on the water surface in the pail then lifts water up the tube into the soda bottle and produces the fountain.

128—Similar to Explanation 127.

129—This demonstrates that the pressure of the atmosphere is equal in all directions at a given point.

130—*c*. The pressure of the atmosphere on the water surface in the pail and on the top side of the rubber sheet is equal to that of a column of water 34 feet high.

If the height from the water surface in the pail to the under side of the rubber sheet is, say 6 feet, the atmospheric pressure on the water surface in the pail is supporting a column of water 6 feet high and its upward pressure on the under side of the rubber sheet is equal to that of a column of water only 34−6=28 feet high.

The difference between the pressures on the two sides of the rubber sheet is equal to that of a column of water 34−28=6 feet high.

Suction. In this experience the 6-foot column of water under the rubber sheet *appears to draw down* the sheet. This *apparent drawing* is called suction. It is a convenient name and we will use it. But you must remember that in every case what appears to be suction is really the difference in pressure at two points.

131—*a*. When you suck air out of the tank you decrease the pressure the air exerts on the part of your arm under the tank. The pressure of the atmosphere on the remainder of your arm and body then forces that part up into the tank.

b. Similar to *a*.

132—Similar to Explanations 130 and 131.

133—When you suck air out of the bottle you decrease the pressure the air in the bottle exerts on the outside of the balloon. The atmosphere outside then forces air into the balloon through the coupling and expands the balloon.

When you let air flow into the bottle again, the pressure on the outer side of the balloon becomes equal to that of the atmosphere outside. The balloon rubber contracts and drives out air until it arrives at its first condition.

134—*b*. The raised diaphragm forces air out of the bottle because the neck is open.

c. The lowered diaphragm lets the air in the bottle expand because the neck is closed.

The expansion decreases the air pressure in the bottle and the atmosphere forces outside air into the balloon.

135—The water inside sinks slowly when you raise the bottomless bottle. It thereby gives the air in the bottle more room and decreases its pressure. The atmosphere outside then forces air and smoke through the smoke producer into the bottle.

136—*a*. When you suck water through the tube, what you really do is this: You increase the volume of your mouth cavity and thereby decrease the pressure of the air in your mouth and in the top of the tube. The atmosphere pressing down on the water in the bottle then lifts water up through the tube into your mouth.

b. You cannot suck water from the bottle because the atmosphere cannot exert pressure on the water in the bottle.

137—*a.* When you invert the upper bottle into the bottomless bottle, air enters the upper bottle and water leaves it until the water level in the bottomless bottle is slightly above the mouth of the upper bottle. Then the air inflow is stopped by the water in the bottomless bottle, and the water outflow is stopped by the atmospheric pressure on the water surface in the bottomless bottle.

b. When the water level drops below the mouth of the upper bottle, air enters the upper bottle and increases the air pressure above the water. This permits water to flow out until the water level is again slightly above the mouth of the upper bottle.

138—*a, b.* When you suck air out of the bottle you give the air remaining in the bottle more room and thereby decrease the air pressure in the bottle. The atmosphere outside pressing down on the water surface in the tumbler or pail then lifts water up into the bottle.

139—When you blow air into the bottle you increase the air pressure in the bottle and this air pressure lifts water up into the large glass tube.

SIPHONS

140—*d.* Three operations follow one another, as follows:

1. The water runs out of the bottle by gravity and gives the air in the bottle more room.
2. The air in the bottle expands and its pressure decreases.
3. The atmospheric pressure on the water surface in the tank forces water up into the low pressure space in the bottle and produces the fountain.

141—*f.* The water runs by gravity from the upper bottle into the lower bottle and it thereby does two things:

1. It decreases the air pressure in the upper bottle and permits the atmospheric pressure on the water in the milk bottle to produce the fountain in the upper bottle.
2. It increases the air pressure in the lower bottle and this increased pressure produces the lower fountain.

142—Similar to Explanations 140 and 141.

143—Directions.

144—The atmosphere at sea level can support a water column 34 feet high if there is a vacuum at the top of the column. In practice the height is only about 30 feet because air and water vapor escape from the water into the top space and exert pressure downward. For these reasons the maximum height of a water siphon is about 30 feet.

The upward pressure of the atmosphere at the bottom of the short arm of a siphon is a trifle less than the upward pressure of the atmosphere at the bottom of the long column because there is less air above it. In practice they are considered to be equal.

The liquid in a siphon always moves up in the short arm and down in the long arm, because the back pressure of the liquid in the short arm is always less than that in the long arm.

145—Similar to Explanation 144.

146—*b.* After you have started the siphon, the longer column of gas in the long arm of the rubber tube is always heavier than that in the short arm, and it makes the gas flow from the bottle into the tumbler. The atmosphere is neutral because it exerts equal pressure on the gas in the bottle and in the tumbler.

147—The water flowing by gravity from the upper bottle into the lower bottle does two things:

1. It gives more space to the air in the upper bottle and thereby permits its volume to increase and its pressure to decrease. The atmosphere then forces air into the upper bottle.
2. It drives the air out of the lower bottle.

148—*a.* The discharge siphon, like any other siphon, starts as soon as the water in the bottle has driven all the air out of the siphon. It continues to run until the water in the bottle falls below the lower end of the short arm.

c. The discharge siphon here consists of the bottle and vertical tube. To start this siphon, after the first discharge, the water in the bottle must rise above the top of the vertical pipe a distance equal to the depth of the U-tube. It must rise this distance to overcome the back pressure of the water in the U-tube when it drives the air out of the siphon.

149—A siphon stops flowing when it fills with air.

a. Here the arms of the siphon are small and the air moving into it at high velocity carries nearly all the water out of the trap.

b. Here the middle arm is so large that the rapidly moving air cannot remove all of the water it contains.

150—The water moving down the discharge tube produces at the top of the siphon a pressure less than that of the atmosphere and the atmosphere outside forces air into this low-pressure space through the vent pipe.

The traps in 149 and 150 illustrate the action of plumbing traps.

COMPRESSED AIR AND EXPANDED AIR

151—When you blow air into the bottle you increase the air pressure in the bottle and this increased pressure produces the fountain.

152—Similar to Explanation 151.

153—Important directions.

154—*Boyle's law is*·

1. The volume of a given weight of gas varies inversely as the pressure on it.
2. The pressure of a confined gas is proportional to the amount of gas in the confining vessel.
3. The pressure exerted by a gas is always equal to the pressure on it.

The following table shows the results if we start with 1 gallon of gas under a pressure of 1 atmosphere and vary the pressure.

Pressure in atmospheres	*Volume in gallons*
2	½
5	⅕
10	⅒
½	2
⅕	5
⅒	10

a. The air in the open bottle was under a pressure of 1 atmosphere and its pressure was 1 atmosphere.

When you fill the inverted bottle half full of water you compress the air to ½ its first volume and its pressure is 2 atmospheres.

b. The compressed air at 2 atmospheres pressure forces the water out against an outside pressure of 1 atmosphere. The moving pressure is then 2−1=1 atmosphere, at the start. It can lift water 34 feet high. As the compressed air expands its pressure decreases and when it again fills the bottle its pressure will be 1 atmosphere.

155—Similar to 154.

156—The air pumped into the bottle increases the air pressure in the bottle and this air pressure produces the fountain.

157—The bottle acts as an air chamber. See Explanations 154 and 155.

158—The plunger moving into the large glass tube compresses the air in the tube and thereby increases its pressure.

This increased pressure drives out the stopper.

159—Similar to Explanation 158.

160—*a.* The water saturates the air with water vapor.

b. When you compress the air and water vapor you do work on them and this work turns into heat which radiates away rapidly.

c. The air and water vapor do work in driving the plunger upward. This work is obtained from the heat contained in them and they cool. The water vapor on cooling condenses to millions of minute water drops which are *visible* as *mist.*

d. When you compress the gases again you do work on them and this work turns into heat. The millions of visible water drops are turned into water vapor by this heat and become *invisible* again.

161—*Henry's law is:* If a gas does not combine chemically with a liquid, the amount of gas dissolved in the liquid at a given temperature is directly proportional to the pressure on the gas and liquid.

Example. A quart of water will dissolve about $\frac{3}{100}$ quarts of air at 32° F. and 1 atmosphere pressure.

If the pressure is raised 2 atmospheres the volume dissolved is doubled.

If the pressure is decreased to $\frac{1}{100}$ atmosphere the volume dissolved is $\frac{1}{100}$ as much and $\frac{99}{100}$ of the dissolved gas leaves the liquid.

d. When you raise the plunger you reduce the air pressure on the water almost to zero and most of the dissolved air bubbles out of the water at once.

The escaping air bubbles are large because the pressure on them is very low, but the actual amount of air in them is small. This is shown by the small size of the air bubble left above the water when you let the plunger down and the pressure on the air becomes 1 atmosphere again.

162—*c.* The air in the tube expands and thereby decreases its pressure when you give it more room.

d. The atmosphere drives the plunger in against the low pressure exerted by the air in the tube.

163—*b.* The atmosphere lifts the water into the syringe.

c. You drive the water out.

164—*c.* You force air from the syringe into the bottle and thereby increase the air pressure in the bottle.

d. This increased air pressure lifts water into the syringe and raises the plunger.

165—The water in the bottomless bottle starts flowing downward due to its weight and due to your upward jerk. Its momentum, or energy of motion, keeps it flowing downward until it has increased the air pressure in the lower bottle slightly above that outside.

This increased air pressure stops the downward flow of water and then forces air bubbles and water upward into the bottomless bottle. The momentum of the air and water keeps them flowing upward until it has made the air pressure in the lower bottle slightly less than that outside.

Then the water starts flowing downward again and the whole operation is repeated time after time until the bottomless bottle is empty.

You use *hot* water because it is much more fluid than cold water. It moves through the coupling much more readily than would cold water.

166—See Newton's third law of motion, Explanation 122. The expanding air moves the water backward and the balloon forward with equal and opposite forces.

167—*a.* You set the air column vibrating so violently that it produces a musical note; and the shorter the air column the more rapid the vibration and the higher the pitch of the note.

b. When you suck air out you decrease the air pressure in the tube and the atmosphere outside lifts the plunger.

When you blow air in you increase the air pressure in the tube and this pressure drives the plunger down.

168—Air is much lighter than water, volume for volume. Hence the mixture of air bubbles and water in the large glass tube is much lighter than an equal depth of water outside the tube; and it is lifted over the edge of the pail by the upward force of this outside water.

169—*The Bernoulli effect is:* A rapidly moving stream of gas or liquid produces a low-pressure space around it, and the greater the velocity the lower is the pressure. See also Explanations 41, 43 to 58, and 50 to 56.

d. The rapid stream of air produces low pressure in the nozzle, and the atmosphere pressing down on the water in the bottle lifts water to the top of the nozzle. Here the rapid stream of air breaks the water up into very small particles.

e. The ping-pong ball remains in the rapid air stream because as soon as it starts to fall out in any direction, there is low pressure on its inner side (Bernoulli effect) and the atmospheric pressure on its outer side shoves it back into the air stream.

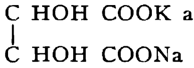
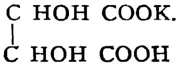
170—See Explanations 52 to 56.

OTHER GASES

171—Carbon-tetrachloride gas (CCl_4) neither burns nor supports combustion and it is 5.3 times as heavy as air. It settles down around the fire and smothers it by excluding air. See Explanations 36 to 39.

172—The fire is extinguished partly by the water and partly by the carbon-dioxide gas (CO_2) which neither burns nor supports combustion and is about 1.5 times as heavy as air.

See Explanation 40 for the chemical equation.

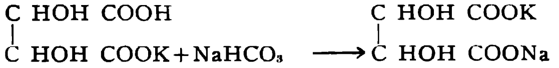
173—The blue package of the Seidlitz powder contains Rochelle salts  $\begin{array}{l}\text{C HOH COOK}\\ \vert\\ \text{C HOH COONa}\end{array}$ and cream of tartar  $\begin{array}{l}\text{C HOH COOK}\\ \vert\\ \text{C HOH COOH}\end{array}$.

The white package contains baking soda, $NAHCO_3$.

Sometimes the baking soda is in the blue package and the cream of tartar in the white.

These salts, when mixed in water, produce about a pint of carbon-dioxide (CO_2) gas. The Rochelle salts take no part in the action, but the cream of tartar, or acid-potassium tartrate, and baking soda react to produce more Rochelle salts, or sodium-potassium tartrate and carbon-dioxide gas.

The equation is:



$$\begin{array}{l}\text{C HOH COOH}\\ \vert\\ \text{C HOH COOK}\end{array} + NaHCO_3 \longrightarrow \begin{array}{l}\text{C HOH COOK}\\ \vert\\ \text{C HOH COONa}\end{array}$$

Cream of tartar + baking soda ⟶ Rochelle salts

$+H_2O\ +CO_2$

+ water + carbon dioxide

The pressure of the gas produces the fountain.

174—The zinc dissolves in the hydrochloric acid and produces hydrogen. The equation is:

$$Zi + 2HCl \longrightarrow ZnCl_2 + H_2$$

Zinc + hydrochloric acid ⟶ zinc chloride + hydrogen

175—The water pressure drives the hydrogen out of the bottle into the balloon.

The balloon rises to the ceiling because hydrogen weighs only about $\frac{1}{14}$ as much as air volume for volume. The buoyant force on the balloon is equal to the weight of the air it displaces. See also Explanations 34 and 35, and the law of Archimedes for gases, Explanation 36.

176—The balloon sinks when the water which clings to its surface makes its weight greater than that of the air it displaces.

177—At 70° F. the weight per 1,000 cubic feet is: for air about 75 pounds, for natural gas about 45 pounds, and for coal gas about 30 pounds. That is, fuel gases are, as a rule, lighter than air, volume for volume. *c*. The bubble rises for the reason given in Explanations 34, 35, and 36.

178—The sodium perborate reacts with boiling water and produces oxygen. as follows:

$NaBO_3 \qquad + H_2O \longrightarrow$
Sodium perborate + water ⟶

$NaBO_2 \qquad + H_2O_2$
sodium metaborate + hydrogen peroxide

$H_2O_2 \longrightarrow H_2O + O$
Hydrogen peroxide ⟶ water + oxygen

b. Pure oxygen is five times as rich in oxygen as is air and supports combustion five times as readily.

Air is about $\frac{1}{5}$ ogygen and $\frac{4}{5}$ nitrogen.

LIQUIDS

179—The upward pressure at any depth under a liquid is equal to the downward pressure at that depth.

The upward pressure on the under side of the paper is equal to the downward pressure of a column of liquid measured from the paper to the surface of the liquid.

180—*b*. The upward force of the water compresses the air in the bottle and the compressed air expands the balloon.

c. The upward pressure of the water at the mouth of the bottle produces the fountain, if the top of the nozzle is below the water level in the pail.

181—The buoyant force of the water is equal to the weight of the water displaced. When you blow air in you increase the amount of water displaced and thereby increase the buoyant force of the water.

When you suck air out you decrease the amount of water displaced and thereby decrease the buoyant force of the water.

182—The full bottle weighs more at first than the weight of the water it displaces. Hence it sinks to the bottom of the pail.

The bottle rises above the bottom as soon as its total weight is reduced to equal the weight of water it displaces. Once it is above the bottom it floats at such a depth that the weight of the displaced water is exactly equal to its total weight.

183—*Newton's third law of motion is:* To every action there is an equal and opposite reaction.

The water stream exerts equal and opposite forces on the water in the pail and on the elbow, and it drives them in opposite directions.

184—*c. The phenomenon of osmosis is:* When a strong solution is separated from a weak solution by a membrane which the liquid can penetrate but the dissolved substance cannot penetrate, the liquid always moves from the weak solution into the strong solution.

In this case water is a very weak solution and it passes through the cellophane into the strong salt solution. This osmosis causes the strong salt solution to rise in the coupling.

185—Similar to Explanation 184.

186—The water moves through each cell wall into the strong blood solution in the cell with such great osmotic force that it bursts the cell and lets the blood out.

187—The soap film on the small bubble has exactly the same contracting force or surface tension as the film on the large bubble, but it acts on a smaller amount of air and produces a greater internal air pressure which forces its air over into the larger bubble.

MORE EXPERIENCES WITH HEAT

188—The dry ice is at a temperature of about minus 110° F., and if the tap water is at say 60° F., the difference in temperature is 170° F. The dry ice turns to gas rapidly and expands the balloon and produces the water streams. See also Explanations 109 and 110.

189—The steam issues from the nozzle at high velocity and drives the turbine.

190—The steam drives the air out of the bottle and leaves nearly a complete vacuum when it condenses to water. The atmosphere outside lifts water into this low-pressure space in the bottle and produces the fountain.

191—The gas burns rapidly and produces a great deal of heat which expands the gases rapidly. This rapid gas expansion is the "explosion" which lifts the can. See also Explanations 92 to 94.

192—These are three ways of showing that air expands when it is heated. See also Explanations 98 and 99.

193—These experiences show that air expands when heated and contracts when cooled.

194—The siphon draws water out of the bottle and leaves more space for the air in the bottle. The air then expands and its pressure decreases. The atmosphere outside then pushes smoke through the burning smoke producer into the bottle.

195—The cool air outside the bottle is heavier, volume for volume, than the hot air inside the bottle. It sinks down around the bottle, enters the bottle at the bottom, and lifts the lighter hot air out through the neck.

The smoke shows the motion of this convection current in air.

196—Each tap on the rubber compresses the smoke quickly and forces a smoke ring out of the mouth of the tank. See Explanation 69.

197—Cold water is heavier, volume for volume, than hot water. The cold water in the upper bottle sinks into the lower bottle and lifts the lighter hot colored water up into the upper bottle. This movement is called a convection current.

198—The air in the bottle expands when you suck air out. It does work in this expansion and this work is obtained from its own heat. It cools and the water vapor it contains condenses into millions of small *visible* water particles or *mist.*

When you let air into the bottle, the atmosphere outside forces the air in and it does work on the air in the bottle in compressing it again. Part of this work turns into heat which warms the air and water particles enough to make the water particles evaporate into *invisible* water vapor. See also Explanation 160.

199—When salt water is boiled the salt remains in the boiler but the water turns to steam and the steam, when cooled, condenses to water free from salt.

200—Water open to the air dissolves a certain amount of air and the cooler the water the greater is the amount dissolved. When the water is heated to the boiling point it gives up most of this dissolved air. See also Experience 161 and its explanation.

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